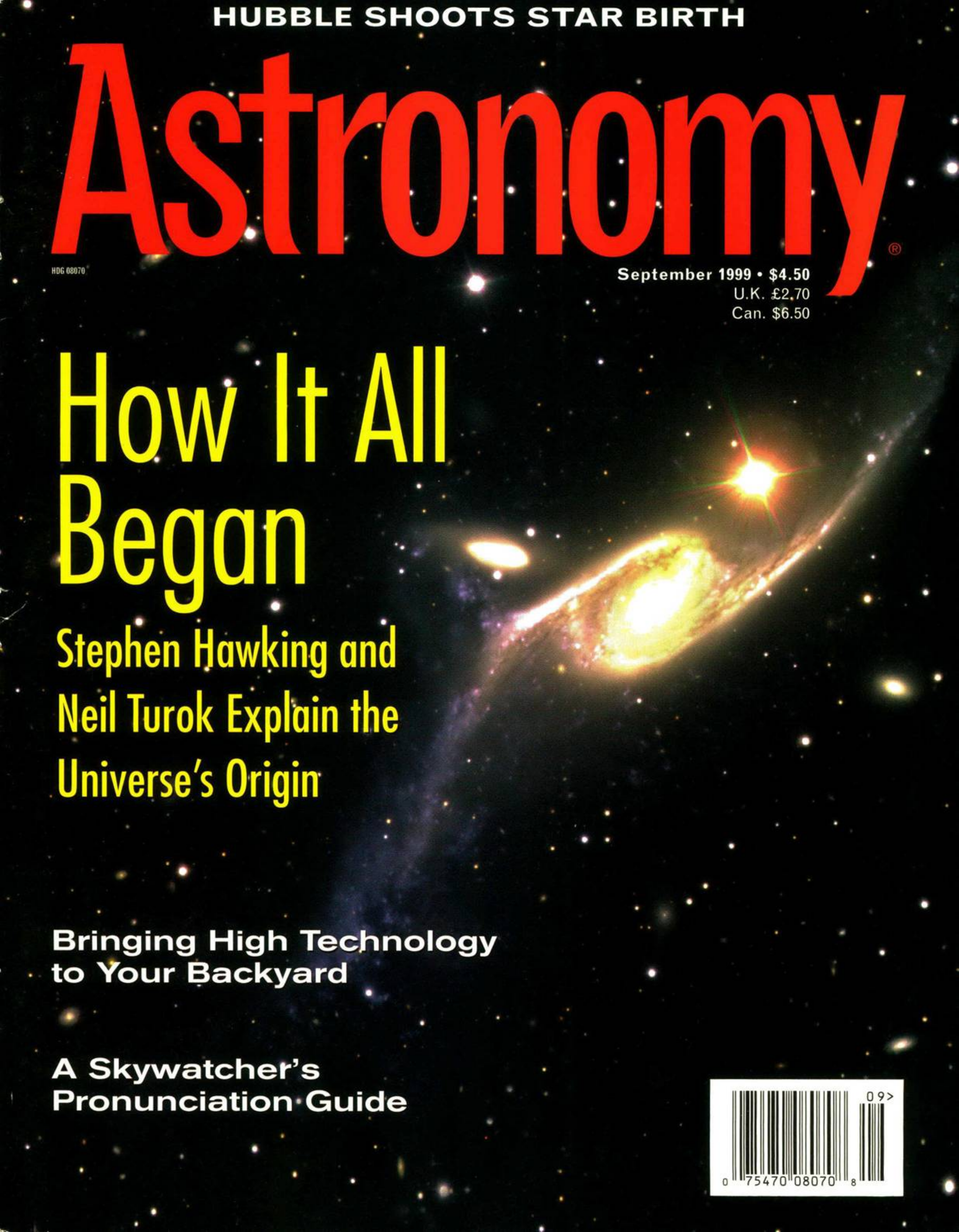

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Astronomy®

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How It All Began

Stephen Hawking and Neil Turok Explain the Universe's Origin

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A Skywatcher's Pronunciation Guide

Now two ETX apertures!
ETX-90EC — $595
ETX-125EC — $895

Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

New Fork Mount Designs with Standard-Equipment Dual-Axis Drive Systems: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

Cordless Operation: The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

Optional Autostar™ Capability: Plug in the optional Meade Autostar computer controller *(see facing page)* for LX200-type operation, including automatic GO TO capability to more than 14,000 celestial objects.

Plus the features that created the ETX revolution:

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

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COMPUTER CONTROL
COMPUTER CONTROL
IN
FOCUS
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SPEED
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Meade ETX-90EC: $595 and ETX-125EC: $895. Each complete as shown, with electronic hand controller; plus packing and shipping.

SPECIFICATIONS: ETX-90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

OPTIONAL SYSTEMS*

#497 Autostar Computer Controller (90, 125)	$149
#880 Equatorial Table Tripod (90)	29.95
#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
#774 Hard Carry Case (90)	99.95
#775 Hard Carry Case (125)	149.95
#932 45° Erecting Prism (90, 125)	49.95
#64 Photo Adapter (90, 125)	34.95
Electric Focuser #1244 (90) *or* #1247 (125)	119.95

**see the Meade accessory ad in this issue.*

AUTHORIZED MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

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Orders: 800-569-4323; Info.: 570-842-1500.

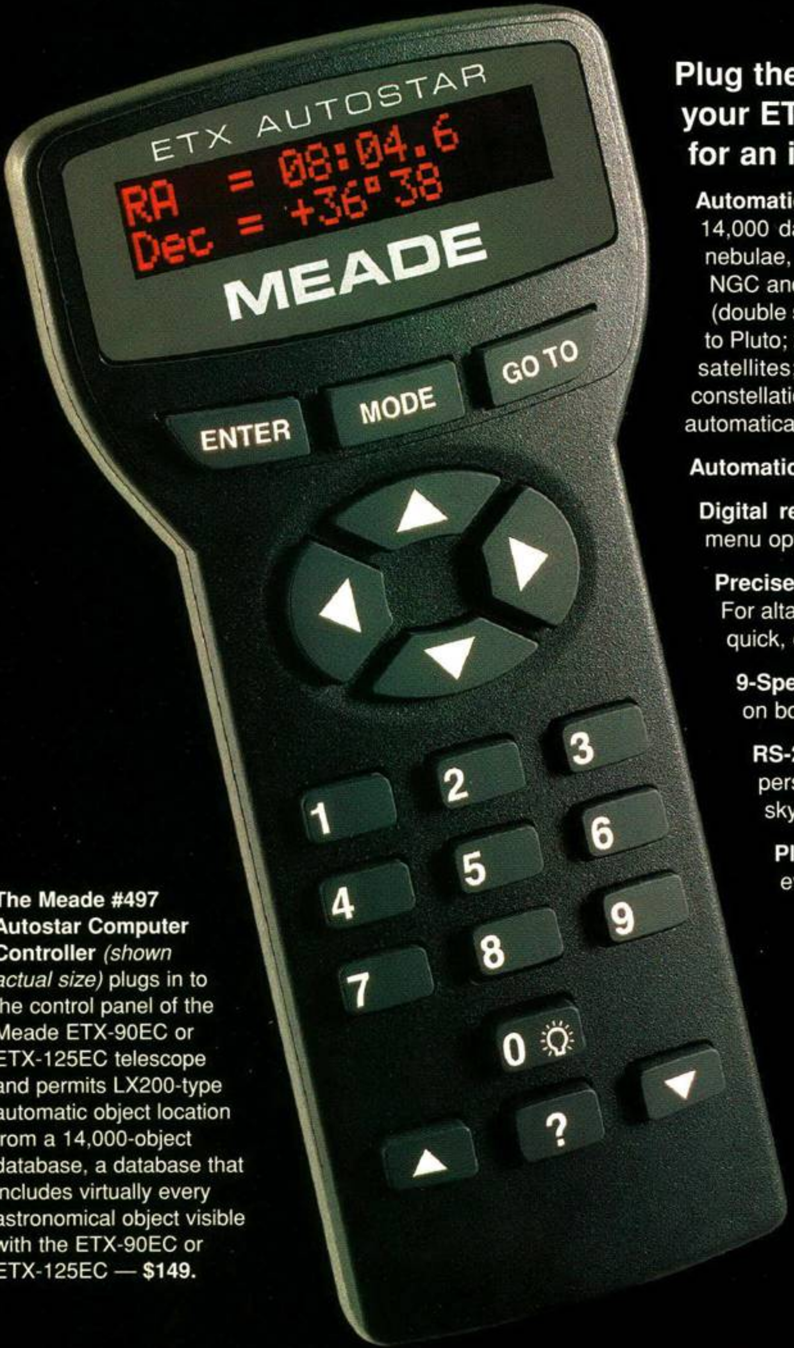
RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

EFSTONSCIENCE, Toronto, Ontario, Canada
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location ...only *$149!*



The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

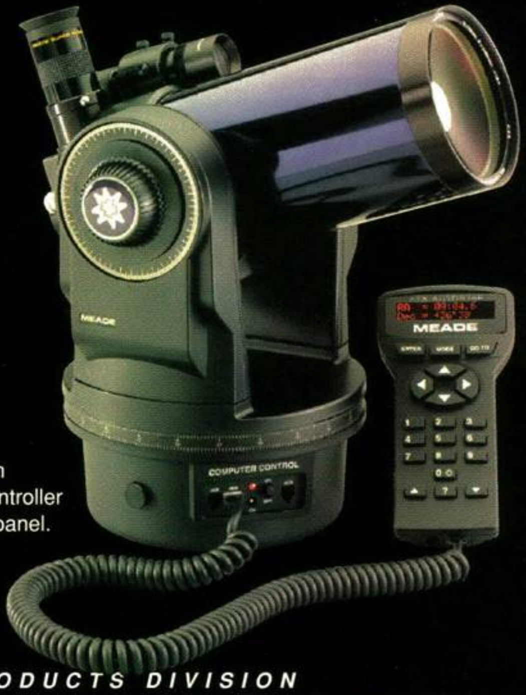
Digital readouts of telescope position (continuously in R.A. and Dec.), menu options, glossary, and utility functions.

Precise sidereal-rate tracking in either altazimuth or equatorial modes. For altazimuth tracking, set the telescope on its drive base and perform a quick, easy alignment.

9-Speed Dual-Axis Operation: Pushbutton operation of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec.

RS-232 Serial Port: For operation of the telescope through a personal computer, using Meade Epoch 2000® sky software or other sky software using the LX200 protocol.

Plus: over 20 other menu options, including guided tours, major event menus, user-defined terrestrial objects, and much more.



(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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Prices shown are suggested U.S. mail-order retail prices.
Patents pending on ETX-90EC, ETX-125EC, and Autostar.

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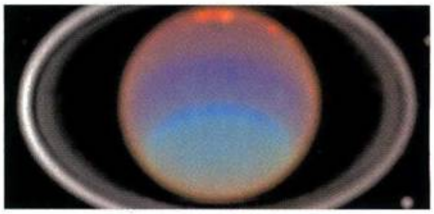

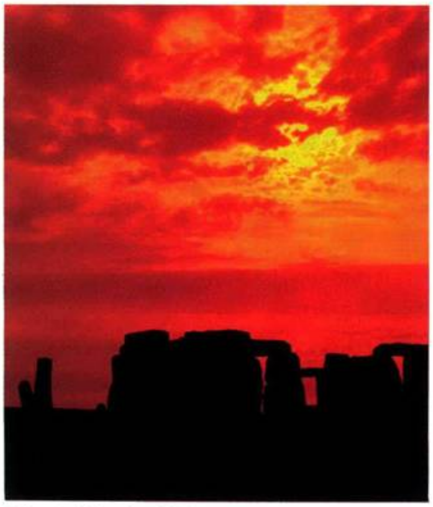

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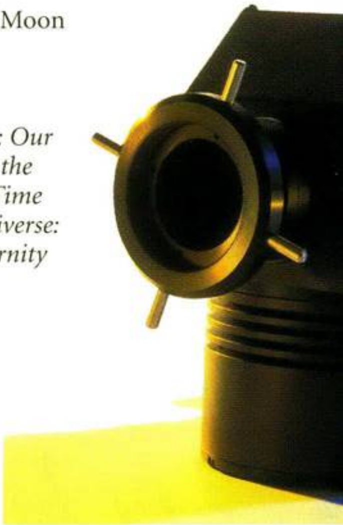

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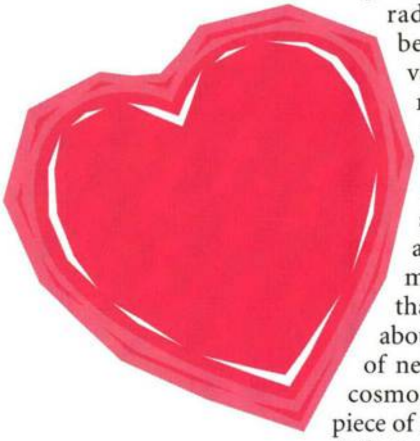
BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Astronomy's Seductions

Coke-can-sized satellites will one day leave Earth for Mars, land there, and then use raw martian materials to build and power much larger satellites capable of traveling to distant stars. It may sound like science fiction, but it was offered as a vision for our future by NASA director Dan Goldin at a recent meeting of the American Astronomical Society. At the same meeting, researchers stopped a few hearts with their announcement of a new rung on the distance ladder, one that could change the age of the universe — again. A report from the Very Long Baseline Array of radio telescopes offers water masers — bright beacons of radio emission amplified by water vapor — in M106 as markers for an absolute measurement to that galaxy (see AstroNews for more complete coverage).



For good reason, AstroNews is the most popular section of *Astronomy*. Things change so quickly in our understanding of astronomy and planetary science that even a monthly magazine has trouble keeping up. It's no secret that readers turn to us for serious information about space missions and their results, discoveries of new extrasolar planets, and new theories of the cosmos (as in "Give Peas a Chance") or just a tiny piece of it ("Crater Crazy").

What we are also beginning to see is that people turn to us for serious, if more personal, matters of the heart. In the last issue of the magazine you may have read about the pen-pal courtship that began between two *Astronomy* readers eight years ago through the classifieds that once ran in this magazine. In the current issue, Hot Shots presents the story of an overheard conversation about the stars that turned into romance and grew into a family.

Some astronomers are taking a renewed interest in biology these days as they begin to hope that we will find signs of life somewhere in our universe. But biology has always influenced astronomers. Just stop and think about how many times you've used the stars and constellations to interest a new friend . . . "Oh look, there's Orion. I bet you've never seen the Orion Nebula. It's in his sword, just below his belt."

It's another good reason to learn about the sky.

Astronomy®

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8" LX10

8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Series 4000 SP26mm eyepiece:** Complements the exquisite imaging of Meade 8" SC optics. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed; and (c) Meade Epoch 2000 Jr. Sky Software with 10,000-object database — all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; Meade #544 8 x 50mm achromatic viewfinder in place of 6 x 30mm viewfinder; and Meade Epoch 2000 Jr. Sky Software with 10,000-object database.

$1149. (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe . . . . **195.**

Electric Declination Motor System for LX10. . . . . **95.**

#2014 Magellan I Telescope Computer System for
LX10 or LX10 Deluxe,
with 12,218-object database . . . . **375.**

The 120-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers.
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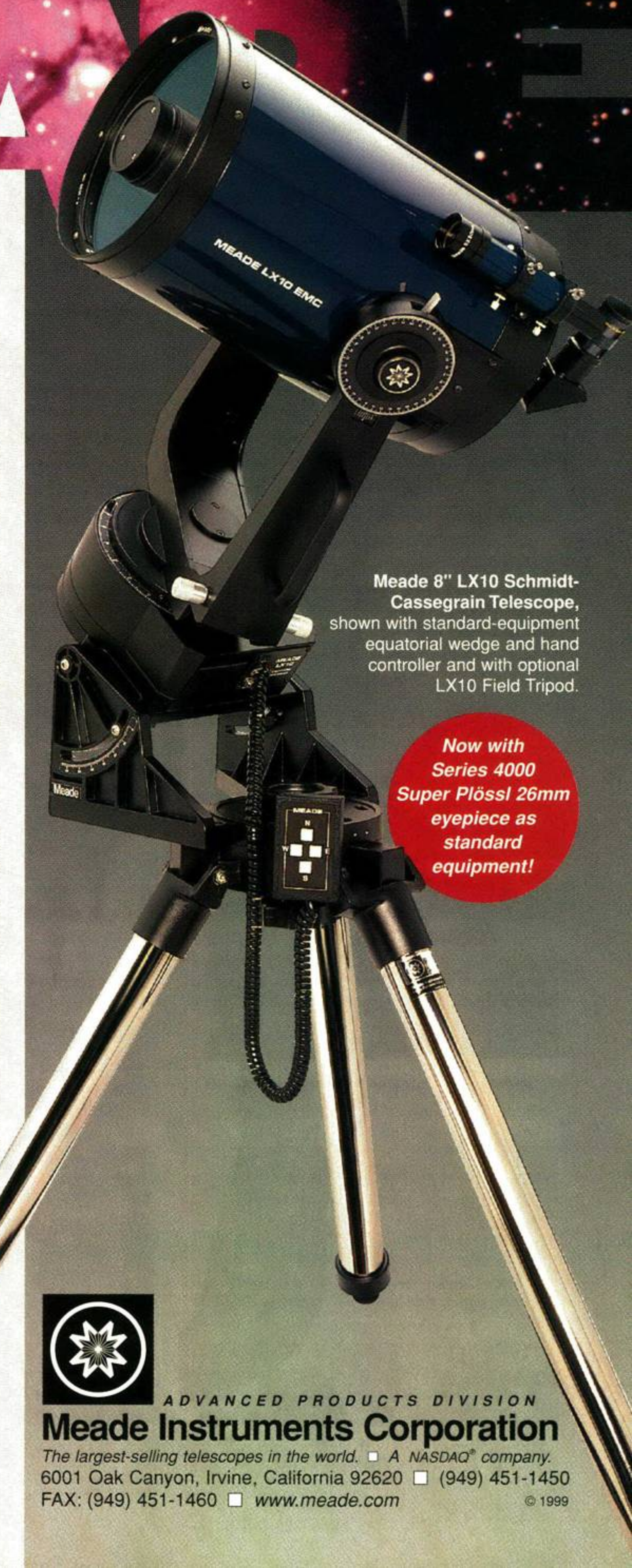

Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

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MEADE LX50

Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below).*

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

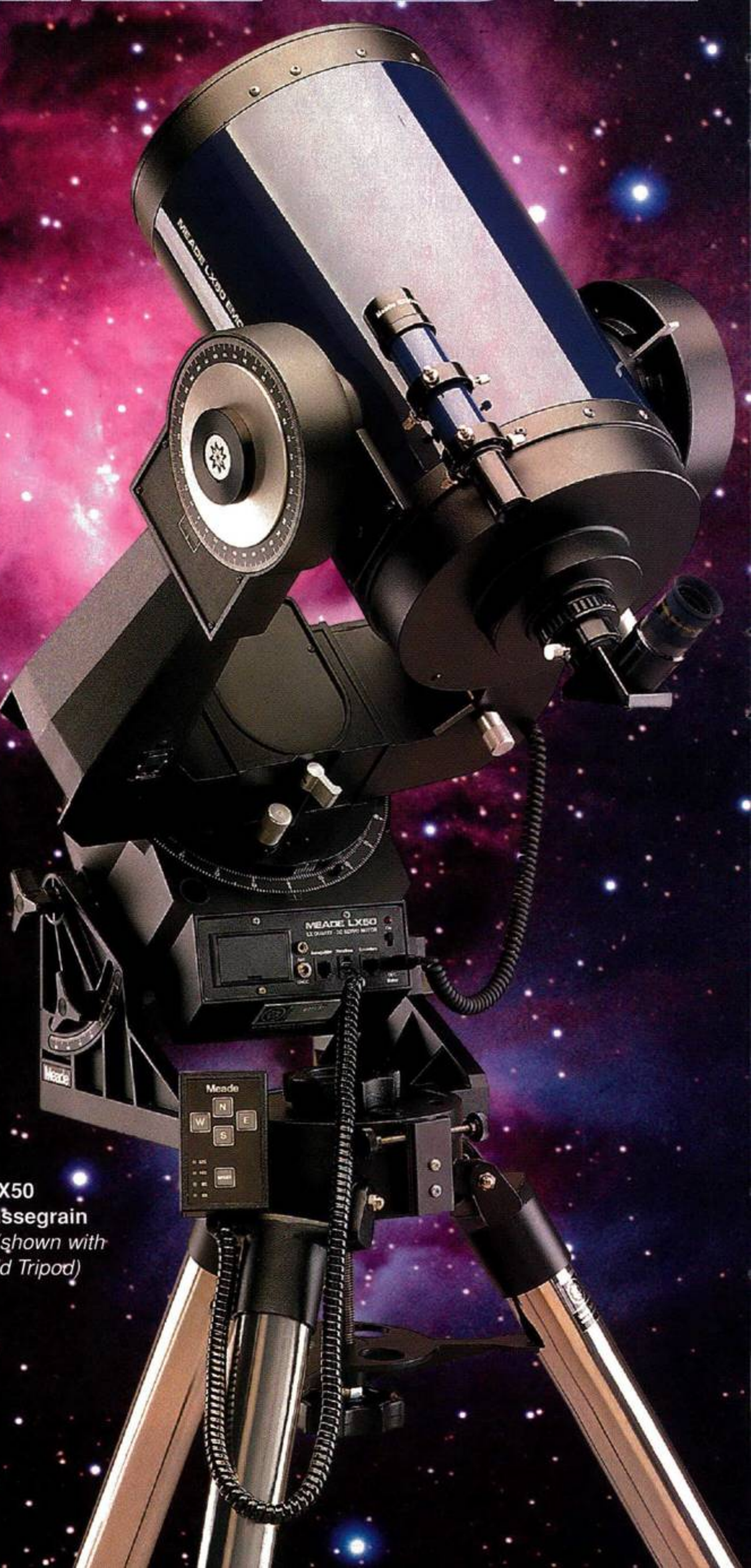
SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

Meade
MEADE LX200 EMC
MEADE LX200
Meade

Meade 10" LX200 Schmidt-Cassegrain Telescope

Prices shown are suggested U.S. national mail-order retail prices.

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. *Standard-equipment includes:*

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

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MEADE STARFINDER DOBSONIANS

Now with Series 4000 Super Plössl 26mm eyepiece as *standard equipment!* Consider these features:

Series 4000 SP26mm Eyepiece (1.25"): The premium SP26mm ocular permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities. This $80 eyepiece is now **standard-equipment** on all Meade Dobsonians.

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: The same strong, spiral-wound Sonotubes™ used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

$270 Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- **1 - Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- **1 - Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- **2 - Meade Series 4000 Super Plössl 9.7mm and 26mm** multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

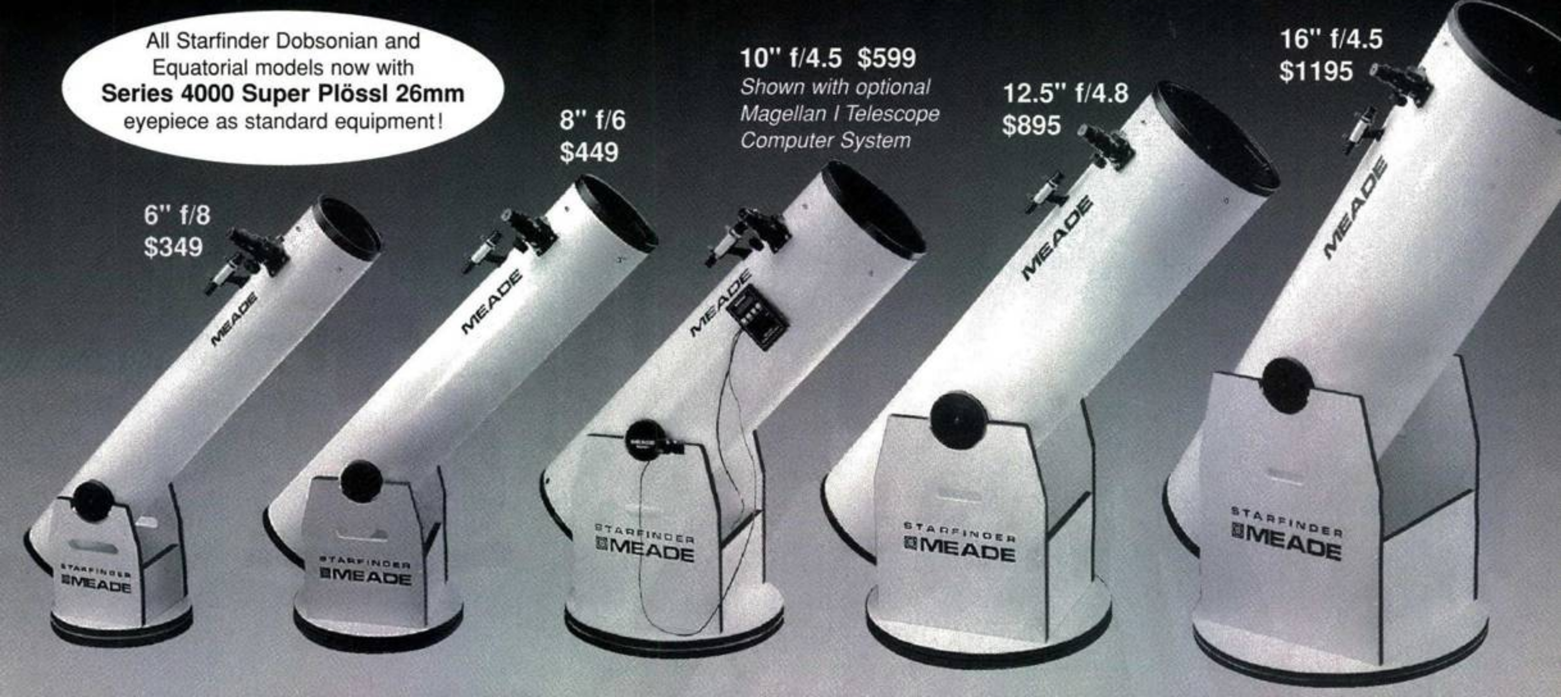
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES *Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.*



All Starfinder Dobsonian and Equatorial models now with **Series 4000 Super Plössl 26mm** eyepiece as standard equipment!

6" f/8 $349

8" f/6 $449

10" f/4.5 $599 *Shown with optional Magellan I Telescope Computer System*

12.5" f/4.8 $895

16" f/4.5 $1195

MEADE
STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 1999-2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.

With DC-powered drive systems for automatic tracking and Series 4000 Super Plössl 26mm eyepiece.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); #637 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
The largest-selling telescopes in the world. ☐ *A NASDAQ company.*
6001 Oak Canyon, Irvine, California 92620 ☐ (949) 451-1450
FAX: (949) 451-1460 ☐ *www.meade.com*
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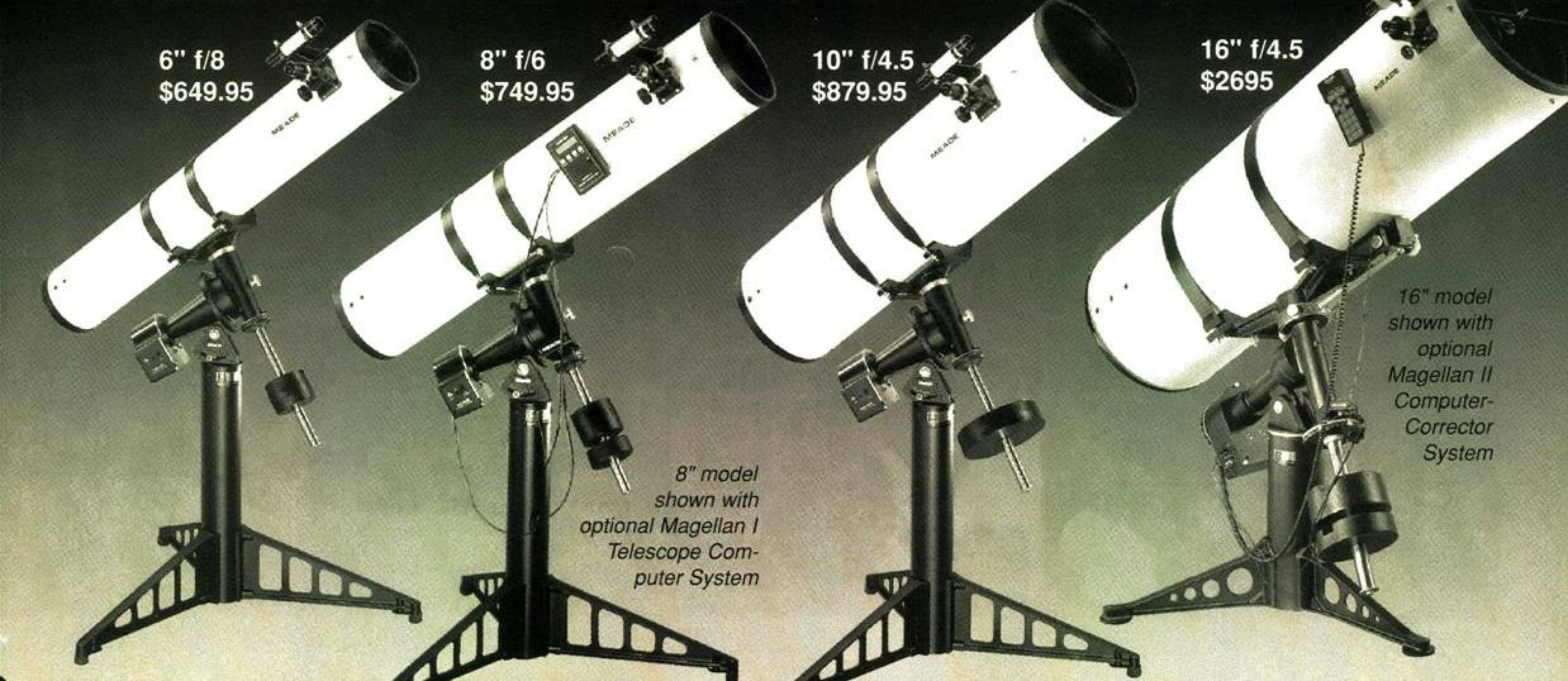
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



6" f/8
$649.95

8" f/6
$749.95

10" f/4.5
$879.95

16" f/4.5
$2695

8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):
6.4, 9.7, 12.4, 15, 20, 26mm each: **$79.95** (4.54)
32mm (52°); **40mm** (44°) each: **99.95** (5.26)
56mm (52°; 2") **199.95** (7.02)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A **49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A **49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56 **49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia. **119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia. **129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia. **159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **149.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

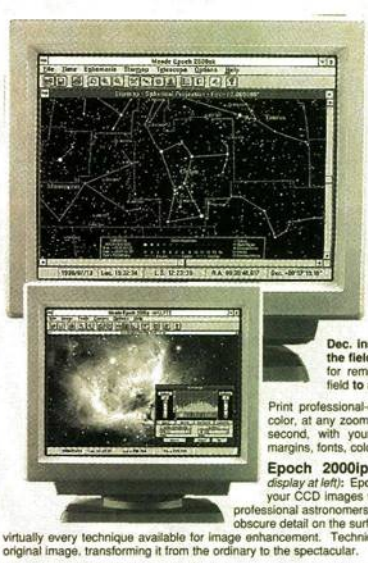
#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644

#647

Epoch 2000® Sky Software



The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left):* Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$199**

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

f/3.3 CCD FOCAL REDUCER

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

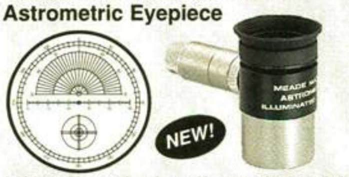
#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

NEW!

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

ETX® Deluxe Field Tripod

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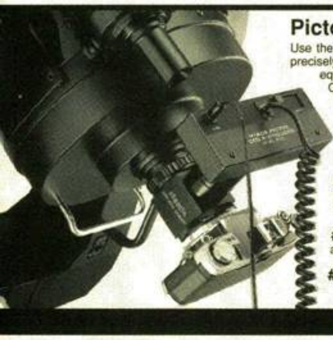

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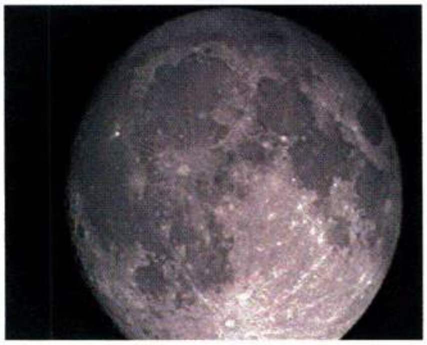
QuickCam Astrophotos

I am using the QuickCam VC, a small, inexpensive electronic camera designed for video conferencing, for taking astrophotos. I liked what I read about the QuickCam but lacked a laptop. In mid-1998, I purchased a laptop (for other reasons) and decided to buy a QuickCam. I was quite surprised to find that I had purchased an inexpensive color camera.

I didn't know if a color camera could take adequate images of the sky and got a bit discouraged. I also did not dare take it apart, since I didn't have any knowledge of this model. However, on the bright side, I read in the instructions that it could take pictures as close as one inch from the subject. Because I am also a model railroader and I model in N scale, getting close to my subject is important for taking realistic-looking pictures. The camera made excellent photos of my models. This confirmed my decision not to take the camera apart.

As an experiment, I tried to point the QuickCam into the eyepiece focuser of my telescope (holding it by hand as an experiment). I first tried this without an eyepiece and then with an eyepiece in the focuser. It turns out that the QuickCam sees everything roughly as our eyes do and needs an eyepiece just as we do. When I tried holding the QuickCam to the eyepiece, I got some reasonably sharp pictures of the moon.

I then hit upon the idea of making a mount for my QuickCam out of PVC pipe fittings. It would allow me to mount the QuickCam to my telescope by using the QuickCam's tripod mount screw to attach it to one end of the PVC mount and thumbscrews to attach an eyepiece to the other end. It turned out to be even easier than I thought and worked perfectly. I found focusing with this arrangement is surprisingly easy. I just focus normally, using the image on the computer screen as my guide. Because the QuickCam can refresh the image in essentially real time, this technique is enormously effective.



QuickCam reveals rugged luna. Steve DePalma

I can only take pictures using eyepieces with long eye relief, due to the setback of the QuickCam's lens from the front of the camera body. I only had two such eyepieces, both of rather low magnification. A 2x Barlow increased magnification.

I have attached a picture of the moon that was taken with an 8-inch, f/6 Dobsonian telescope. — *Steve DePalma, Holbrook, New York*

Contaminating Earth

"Men In Black" (July 1999) discussed the on-Earth activities regarding contamination control of Mars specimens. Why doesn't NASA use the new International Space Station as a way station for specimens returning from Mars. Nothing should get down to Earth until it has been thoroughly tested in Earth-orbit aboard the Space Station. And if by chance an organism is dangerous and loose aboard the station, all we would have are some sick or dead scientists and not a dead population. Detach the contaminated section and push it into the sun. — *William D. Kuehler, Jr.*

NASA is committed to using the safest methods to return martian samples to Earth and will maintain the returned samples in strict containment until they are proven nonhazardous. In previous studies, NASA has examined a variety of options for returning a martian sample and testing it, including the possibility of conducting the analysis on an orbital space station.

Another alternative is the use of a terrestrial laboratory of the sort used previously for the Apollo missions, and in use currently by organizations such as the Centers for Disease Control and Prevention to safely study known dangerous organisms on Earth.

These studies have suggested that the additional complications of returning a sample to a space station would outweigh the temporary benefits of orbital containment. In fact, the very phenomena that we wish to study on such a station — the response and behavior of materials and biological systems in microgravity — will, for the foreseeable future, preclude us from being able to effectively characterize extraterrestrial samples in the space station environment.

So far, it appears that the safest and most effective place to assay the samples for hazard is within a containment facility built on Earth. — John D. Rummel, Planetary Protection Officer, NASA Headquarters, Washington, D.C.

The Equation of Time

In *Astronomy*'s Sky Show (June 1999), it is stated that the size of the equation of time is determined largely by the obliquity of the ecliptic. The eccentricity of Earth's orbit has an effect that is "measurable" but "not large enough to factor into [the authors'] broad-based discussion." The equation of time ranges from +16 to –14 minutes. If Earth's orbit were circular the extremes would be +/–10 minutes. The effect of Earth's orbital eccentricity is thus not negligible. Indeed, if Earth moved in its present orbit but had its spin axis perpendicular to the ecliptic, the equation of time would still reach +/–7.5 minutes. — *Gerry Taylor, Scotland*

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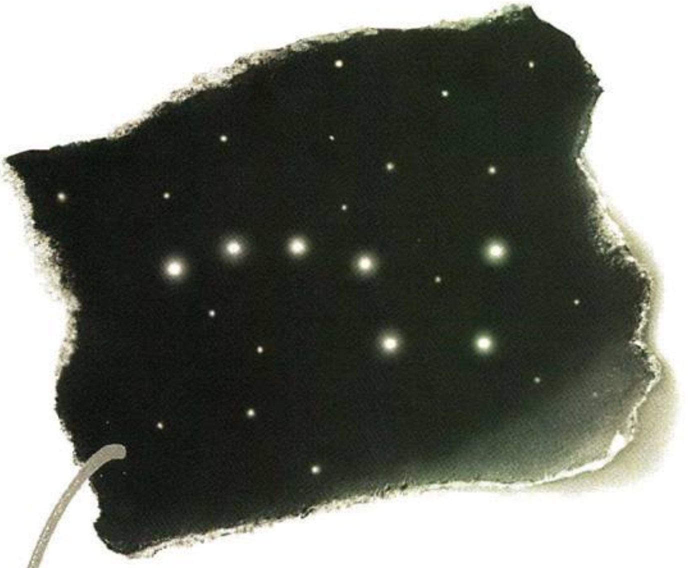

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Indeed, both the eccentricity of Earth's orbit and the tilt of the axis (obliquity) contribute to the difference between sundial time and the standard time on our clocks. When I said that the eccentricity effect is not large enough to factor into "my broad-based discussion above," I was referring not to this equation of time but to the offset of earliest sunrise/latest sunset from the June solstice. I apologize for not making that reference clear.

The offset is noted often by morning television news shows. I had initially hoped that a sound bite of "Earth's elliptical orbit" would work until I consulted Jean Meeus' excellent book Mathematical Astronomy Morsels. *The contribution from eccentricity actually runs opposite to the one from axis tilt near the summer solstice, but it is small enough that eccentricity does not change the pattern of the offset, just reduces the size. Meeus' book reveals a lot of neat things about the solar system clockwork. Despite the title, you can ignore the math (if you need to) and still understand the morsels. Also, check out www.analemma.com where you can adjust the contributions and see the result on-line. —* Martin Ratcliffe

Radio Man

I enjoyed your story on John Kraus (June 1999); however, you didn't mention his most famous antenna design. John is an amateur radio operator and years ago designed a simple but effective four-element "beam" antenna. John's call sign is W8JK, and this antenna is known all over the world as the W8JK antenna. — *Bob Branch (KJ7I is my call sign), Pine, Arizona*

Correction

In the July Sky Show, we meant to identify the magnitude of Kalliope as 11.3, but instead dropped a "one" and claimed the asteroid was much too bright at magnitude 1.3. We apologize to those expecting such a bright "star."

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2x Barlow

$50
Multi-coated and under 3 inches long. Weighs just 4 ounces.

APO 2x

$80 3-element Apochromatic! Shorty design, only 2.75" long and just 5 oz.

Custom Fitted Hard Case

$100 Hardshell case with pre-cut foam interior precisely fits your 90mm ETX. Holds tripod legs, 5 eyepieces, and more! 13x17x7".

Lithium AA

3/$10.50
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Powers your ETX 4 times longer than alkaline-AA's.

Moon Filter

$18
Preserve your night vision. Threads to back of 1.25" eyepieces.

Solar Filter

$72
Machine polished Glass filter. Triple coated. Anodized aluminum cell.

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Plossl Eyepieces $50 ea. 2/$90
Choose from 7.5mm, 10mm, 12.5mm, 17mm, or 20mm
32mm/40mm $75 ea. both/$130

Deluxe Soft Case

Fits 90mm ETX's

$79
Features padded contoured shoulder strap. Full length front pocket has 5 inner pouches for accessories. Thick padding on all sides and bottom. Zippered top plus rain flap. Water-resistant cordura, 17.5" x 5.5" x 9.5".

Dew Shade

$32
New! Slides out for use and retracts back onto tube for storage!

MotoFocus

$100
Fits 90mm old or new ETX's! Variable speed electric focuser. Easy installation!

Polar Site

$50
Makes polar alignment easy. For original ETX only. Folds in for storage.

Piggy Brkt.

$60 90mm
Clamps around optical tube and includes a small counterweight.

WedgePod

JMI
$195
90mm models only

Built-in wedge and storage for 4 eyepieces. Weighs 8lbs. Adjusts 22-52".

Field Tripod

Bogen
$159

Weighs just 8 lbs. Adjusts 27-70". Anodized aluminum.

90° Plug

$1.25 ea.
Fits into top 90° opening. Keeps dust and dirt out.

SCT Adapt.

$32 Lets you attach standard Schmidt-Cassegrain accy. onto your ETX.

Tele Ext.

$32
Fits onto visual back (at right). Shorty design. Only 3" long.

Vis. Back

$32
Lets you put any standard 1.25"-barrel accy. into the rear opening of your ETX.

Wide Field

$100
Deluxe Prism
Increases field-of-view by **64%!**
Requires visual back shown at left.

T-adapter

$35
Mounts to rear of ETX. Accepts all standard t-rings for 35mm SLR's.

Quickfinder

$40 This Rigel zero-power finder works like a Telrad but is only 1.5"x1.5"x4".

Kwik Focus

$32 90mm
$37 125mm

Makes focusing a quick, accurate procedure.

Check out the latest ETX Accessories at www.shutan.com

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STAR HOPPER® DOBSONIANS

Dobsonian telescopes, by design, combine the strong performance of a Newtonian system, with a simple altazimuth mount. Celestron's Dobsonian design, the Star Hopper® is great for beginners because it's very easy to use and quite economical, yet has advanced features even an experienced observer will appreciate.

STAR HOPPER 4½

- 4½" (114mm) Aperture - 910mm Focal Length, f/8
- Aluminum Optical Tube
- High Quality, Smooth Dob Mount
- Standard 1¼" Accessories: 25mm SMA Eyepiece (36x) and Focuser
- 5x24 Finderscope
- Collimation Tool Standard
- Weight: 18 lbs.

Celestron's Star Hopper 4½ is unique, small Dobsonian telescope that's great for both your own use and for gift-giving. The mount and telescope tube are shipped fully assembled in one box, ready for you to begin observing immediately.

4½"

8"

STAR HOPPER 6 & 8

- 6" (152mm) - 1220mm Focal Length, f/8
- 8" (203mm) - 1220mm Focal Length, f/6
- Precision annealed Pyrex primary mirrors - better than glass used by some competitors, ensure faster temperature stabilization and the highest quality steady optical figure
- Optics are diffraction limited
- Multicoated Primary Mirrors
- Teflon and Nylon surfaces guarantee smooth performing mechanics
- Unique Balance System
- 25mm SMA Wide Angle Eyepiece - 1¼"
- 5x24 Finderscope
- 1¼" Rack and Pinion Focuser
- Collimation Tool - very useful and unique to Celestron
- Made in the U.S.A
- Weight: 6" @ 39 lbs., 8" @ 55 lbs.

6" and 8" Dobs offer one of the best values for an astronomer. Large primary objectives and affordable prices allow first-time astronomers to explore deep-sky objects with ease.

The Dovetail Balance Bar allows for precise balancing of the tube, making the smoothest possible movement. No need to add counterweights!

In summary, *Astronomy Magazine* says, "Star Hopper® is a milestone on the road toward a better commercial Dobsonian telescope. Star Hopper's innovative mirrors, mirror cell and adjustable altitude bearings, combined with its crisp, sharp images more than meet what every Dobsonian owner hopes to have in an easy to use, backyard telescope."

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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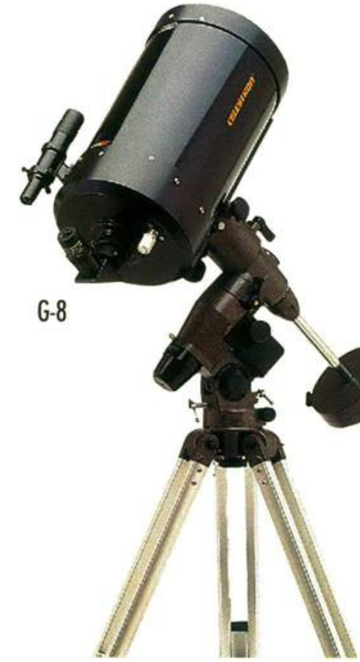
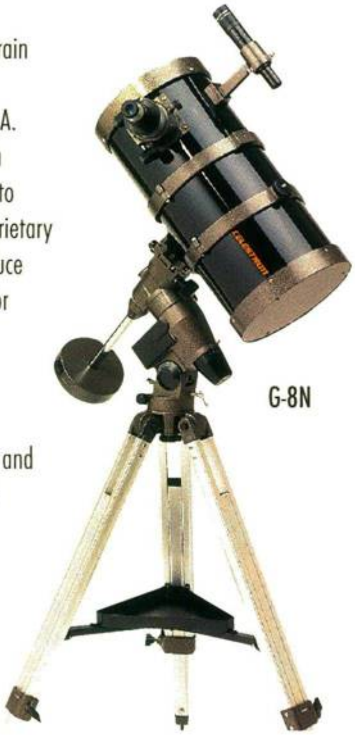
G-8, G-8N & G-9¼ TELESCOPES

Large Aperture Telescopes with Unequaled Optical Excellence + a Superb German Equatorial Mount = Real Value


G-8

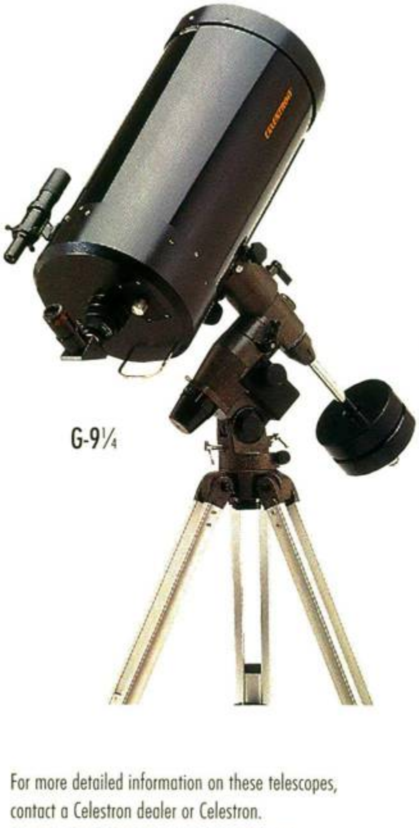
OPTICS: **G-8 Telescope** – 8" f/10 Schmidt-Cassegrain
G-9¼ Telescope – 9¼" f/10 Schmidt-Cassegrain
G-8N Telescope – 8" f/5 Newtonian

Both of the Schmidt-Cassegrain systems are made in the U.S.A. and feature hand-figured, diffraction-limited optics along with Starbright® multicoatings. The fast (f/5) Newtonian is made to Celestron's uncompromising standards. The Newtonian's proprietary optical design incorporates an auxiliary correcting lens to reduce aberrations, flatten the field and allow a short tube design for added portability.


G-8N

MOUNT: All three telescopes use the CG-5 German mount. The CG-5 mount is the newest generation of Celestron's German mounts which was designed by Celestron and replaces the old style, outdated GP mounts. Both axes of the equatorial mount have precision worm gears for extremely smooth motion and excellent tracking accuracy.

This heavy-duty mount easily delivers jitter-free images and the sturdy adjustable height aluminum tripod has excellent damping characteristics. A convenient deluxe accessory tray adds to the stability of the system.


G-9¼

ACCESSORIES: Numerous accessories are available for these telescopes. Included as standard eyepieces – 25mm SMA - 1¼" (81x) on the G-8, 26mm Plössl - 1¼" (90x) on the G-9¼ and 20mm Plössl - 1¼" (50x) on the G-8N. The standard finderscope is a 6x30 with the G-8 and G-9¼ and a 9x50 with the G-8N.

Some of the more useful accessories for these telescopes are the polar alignment scope (for fast polar alignment) and DC motor drives for automatic tracking of celestial objects. Celestron offers a choice of motor drives – a single axis (R.A.) or dual axis. They are powered by four D-cell batteries (not included). Both models include a hand controller with built-in drive corrector for astrophotography.

Computerize your telescope by adding the optional Advanced Astro Master® which is easily installed. Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery. Contains an RS-232 serial interface to enable usage with programs like "The Sky" by Software Bisque.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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BRING THE UNIVERSE HOME WITH THE G-3 & G-5

Saturn's rings, galaxies light years away, bees buzzing in a patch of flowers - these images and many, many more can be yours with Celestron's new ultra-portable **G-3** and **G-5** telescopes. These large aperture, multipurpose instruments are full-featured systems ideal for terrestrial viewing, astronomical observing, telephotography as well as astrophotography and they come complete with equatorial mount, tripod, accessory tray and CD-ROM software.

They are the perfect sky-watching tools for amateur astronomers of all levels. Whether you're a first time user or a seasoned cosmic observer, you will appreciate the bright images, sharp contrast and exquisite detail provided by Celestron's legendary U.S.-made optics. Meticulously hand-crafted for optical excellence, the **G-3** and **G-5** are manufactured under strict quality standards.

OPTICS:

- **G-3** - 3½" aperture, 1000mm f/11
- **G-5** - 5" aperture, 1250mm f/10

The **G-3** (Maksutov-Cassegrain optical design) and the **G-5** (Schmidt-Cassegrain optical design) deliver razor sharp images over a wide field. They both feature Celestron's world renowned hand-figured diffraction limited optical systems. Starbright® optical multicoatings provide maximum reflectivity and increased light transmission.

MOUNT AND MOTOR DRIVE

An ultra-durable German equatorial mount is standard on the **G-3** and **G-5**. Setting circles and slow motion controls make it easier to locate and track objects manually. Setup is a breeze with the adjustable height aluminum tripod complete with deluxe accessory tray.

Automatic tracking of celestial objects is yours with the dual speed, single axis motor drive models as pictured above. A hand controller makes observing more fun as objects are easier to center. The built-in drive corrector, which runs on 4 "D" batteries, makes astrophotography possible. Non motor driven models are also available.

STANDARD ACCESSORIES

A 25mm SMA eyepiece - 1¼" (40 power - **G-3**/50 power - **G-5**) is included. The **G-3** includes an 8x20 erect image finderscope and the **G-5** has a 6x30 finderscope.

A fun and educational CD-ROM, "The Sky Level 1 for Celestron," features a 10,000 object database and allows you to print your own custom sky charts.

Test out the new **G-3** and **G-5** at your Celestron dealer today and bring the Universe home.

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HD TELESCOPES

HEAVY-DUTY TELESCOPES OFFER MORE VALUE THAN YOU MIGHT THINK!

C114-HD

HD SERIES TELESCOPES – two refractors – an 80mm (3.1") with a focal length of 900mm (f/11) and a 102mm (4.0") with a focal length of 1000mm (f/10); two Newtonians – a 114mm (4.5") with a focal length of 900mm (f/8) and a 150mm (6.0") with a focal length of 100mm (f/7).

All models come standard with a 6x30 finderscope and a premium 20mm Plössl 1¼" eyepiece.

OPTICS – all **HD** series telescopes have diffraction limited, premium optics manufactured to Celestron's uncompromising standards. The star images are classic textbook Airy disks. The Newtonians have multicoated optics and the refractors are fully multicoated to provide higher light transmission yielding bright, high contrast images.

C102-HD

The refractors have very good color correction. The 150mm Newtonian uses a state-of-the-art proprietary optical design incorporating an auxiliary correcting lens to reduce various aberrations, flatten the field and allow the tube length to be shortened – and it is superior to most fast parabolas.

MOUNT AND TRIPOD – the **HD** telescopes use the CG-4 German equatorial mount. It is a precision, heavy-duty mount which is upgraded and much better than the older polaris mounts.

The precision worm gears are extremely smooth in motion and the tracking accuracy is excellent. Optional motor drives make astrophotography easy and fun.

The tripod is a sturdy, adjustable height unit made of aluminium and it includes a heavy-duty accessory tray.

In addition, the 102mm refractor is offered with a **HD** altazimuth mount. This mount is easy to use and has slow motion controls (flexible cables) on both axes to allow for quick and easy pointing and tracking.

The superb optics with rigid mount and tripod of the **HD** telescopes allow you to enjoy awesome details of our moon such as craters, rills and mountain ranges; Saturn and its rings; Jupiter with its belts and moons; Mars, Venus and Mercury; deep-sky objects such as galaxies, nebulae, double stars and star clusters.

C150-HD

C102-AZ

C80-HD

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New Topographic Map May Explain Martian History

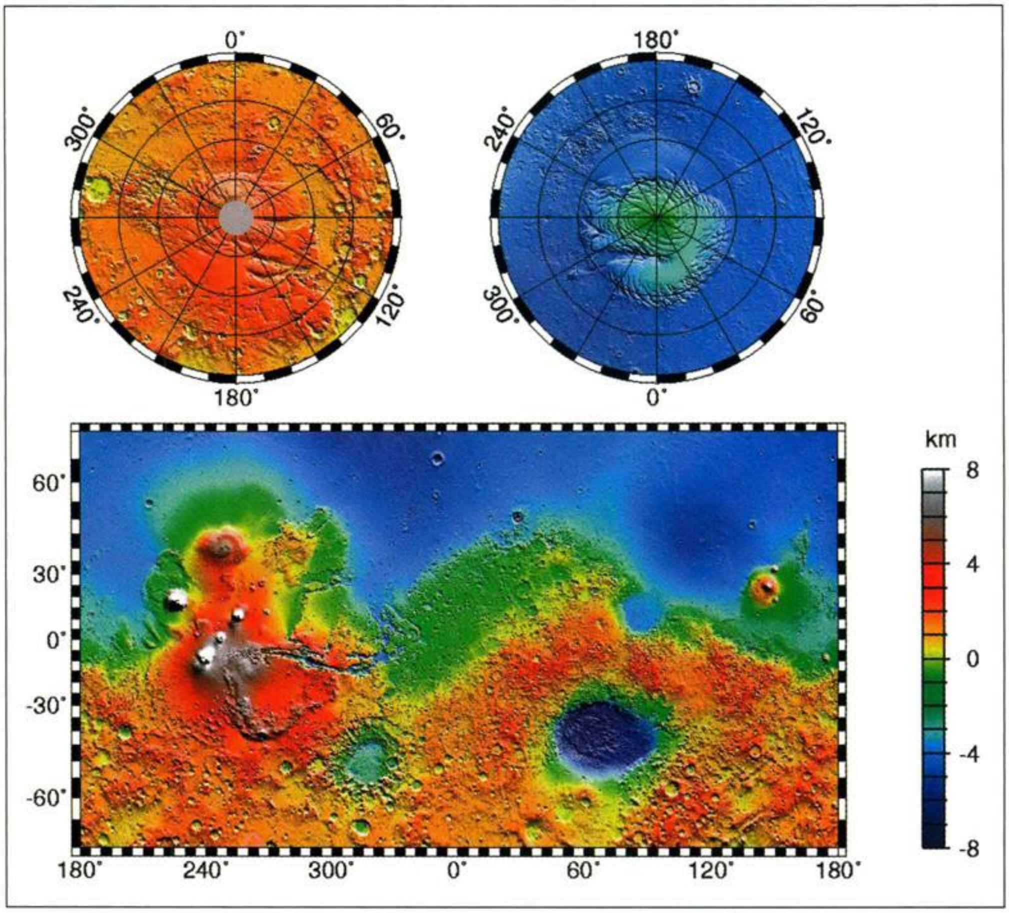
PLANETARY SCIENCE

▶ A new 3-D map of Mars generated by NASA's Mars Global Surveyor satellite shows that the planet's highs are higher and its lows are lower than scientists had expected. The planet's range of elevation is 19 miles (30 km), or 50 percent more than Earth's.

Combined with Surveyor measurements of magnetized rock that suggest an early epoch of volcanic outpourings along fissures and alternating magnetic fields, the Surveyor mission is providing an information bonanza to planetary scientists. "Together they will help us eventually synthesize the geologic history of the planet," says Bruce Jakosky, a University of Colorado geologist not involved in the mapping experiment. "It is very clear that we have a spectacular data set."

That data set is growing by 900,000 measurements a day. The Mars Orbiter Laser Altimeter (MOLA) instrument repeatedly bounces laser light off the martian soil and records its return. Each laser pulse generates one elevation measurement.

The MOLA instrument confirmed that the Hellas impact basin is much deeper than previously thought: It could easily contain Mount Everest.



NASA, JPL

These map projections show the elevation range of the martian surface from +70° to −70° latitude, and the south pole, upper left, and north pole, upper right.

A report on the map published in the May 28 issue of *Science* was coauthored by 19 scientists, led by David E. Smith of the Goddard Space Flight Center and Maria T. Zuber of the Massachusetts Institute of Technology. The team reported that if both polar ice caps suddenly melted, the liquid would cover the planet to a depth of 66 to 100 feet. While something other than flowing water could have sculpted Mars (such as lava flows or impacts) the false-color topographic map shows the lower elevations of the Northern Hemisphere in marine blue. — Rex Graham

SPACE METEOROLOGY

Storm Chasers Combing the Cosmos

▶ These scientists know they are not in Kansas anymore when they spot planetary storms that would make our

CELESTRON BINOCULARS AND SPOTTING SCOPES–

GREAT FOR ASTRONOMY AND BEYOND . . . .

Celestron offers dozen of binoculars and spotting scopes suited for a wide variety of uses - astronomy, backpacking, birding, boating, camping, concerts, fishing, flying, hiking, hunting, long distance observing, museum visits, nature study, sporting events, surveillance, target shooting, theater/opera, travel, view home applications and more. Whatever your optical needs may be, Celestron has a binocular or spotting scope that's right for you.

ENDURO
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Enduro 10x50

Featured here are just a few of our numerous binoculars that are perfect for astronomy. All have large aperture, long eye relief and are tripod adaptable.

Enduro® – Unbeatable price for high quality optics! Rubber covered for rugged use. Large center focus knob makes focusing easy.

	FOV	ER
7x50	6.8°	13mm
10x50	7.0°	13mm
8x56	6.0°	21mm
10x60	5.3°	20mm

Ultima 9x63

Ultima® – Superb image quality that rivals the best European binoculars. Fully multicoated for the highest contrast level possible. Soft leatherette finish for a smooth, comfortable grip.

	FOV	ER
7x50	7.0°	20mm
10x50	5.0°	21mm
8x56	6.1°	21mm
9x63	5.4°	21mm

Giant
20x80 Deluxe

Giant – A 20x80 multicoated deluxe model of premium quality. Structural reinforcement of the main body and super rigid photo tripod adapter ensure rock solid performance.

80mm Wide View

Spotting scopes are thought of for terrestrial applications. However, with apertures of 80mm and larger they can be used as - altazimuth telescopes for astronomy, imaging lenses, guidescopes and piggyback lenses among others. Featured here are just two models of exceptional capability.

80mm Wide View™ – An 80mm aperture refractor with fully multicoated optics offers excellent resolution and high contrast levels. Fast, wide field - this 400mm f/5 instrument is super portable. Standard are two multicoated Plössl 1¼" eyepieces (20mm and 10mm), 45° erect image diagonal, 6x30 finderscope and built-in T-adapter for photo applications.

C5 Spotting Scope – A large 5" aperture, 1250mm f/10 Schmidt-Cassegrain optical system. The multicoated diffraction limited optics are made in the U.S.A. The f/10 provides for a variety of photographic endeavors and makes possible its light weight (6 pounds) and compact size (11 inches). Standard is a 26mm multicoated Plössl eyepiece - 1¼" 45° erect image diagonal and 8x20 erect image finderscope.

C5 Spotting Scope

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hurricanes look tiny. The solar system seems to be brimming with bad weather.

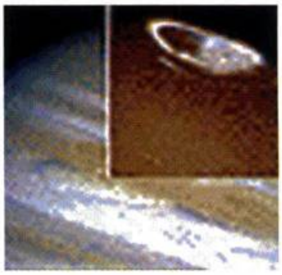
Storm chasing astronomers have even found titanic swirling storms on a distant brown dwarf called LP944-20. Chris Tinney of the Anglo-Australian Observatory and Andrew Tolley, a student at the University of Oxford, discovered the storms.

The study of weather outside the solar system, a new field of research that Tinney calls "astro-meteorology," is blossoming. "We'll be learning more about clouds, wind speeds, how weather links with magnetic activity. You name it: It all has to be discovered."

Within the solar system, the Hubble Space Telescope recently spotted a giant cyclone in the north polar region of Mars. The sublimation and condensation of material in the polar caps dominate martian weather. "The storms form after the northern seasonal carbon dioxide cap has sublimed but before the southern carbon dioxide cap has started to form," says Bell.

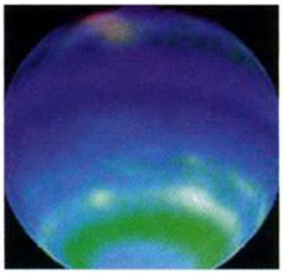
Astronomers recently discovered "auroral electrojets" on Jupiter, "spring storms" on Uranus, supersonic winds on Neptune, and an upwelling of warm air on Saturn that generated a storm the size of the 7,900-mile diameter of Earth. All the planetary storms are helping astronomers understand how weather works. "We've learned much about things such as the greenhouse effect, nuclear winter, and global warming here on Earth," says Cornell University planetary scientist Jim Bell. — Kelly Whitt

STORMS BEYOND EARTH

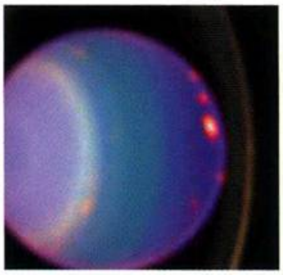


Auroral electrojets on Jupiter

Polar cyclone on Mars



Supersonic winds on Neptune

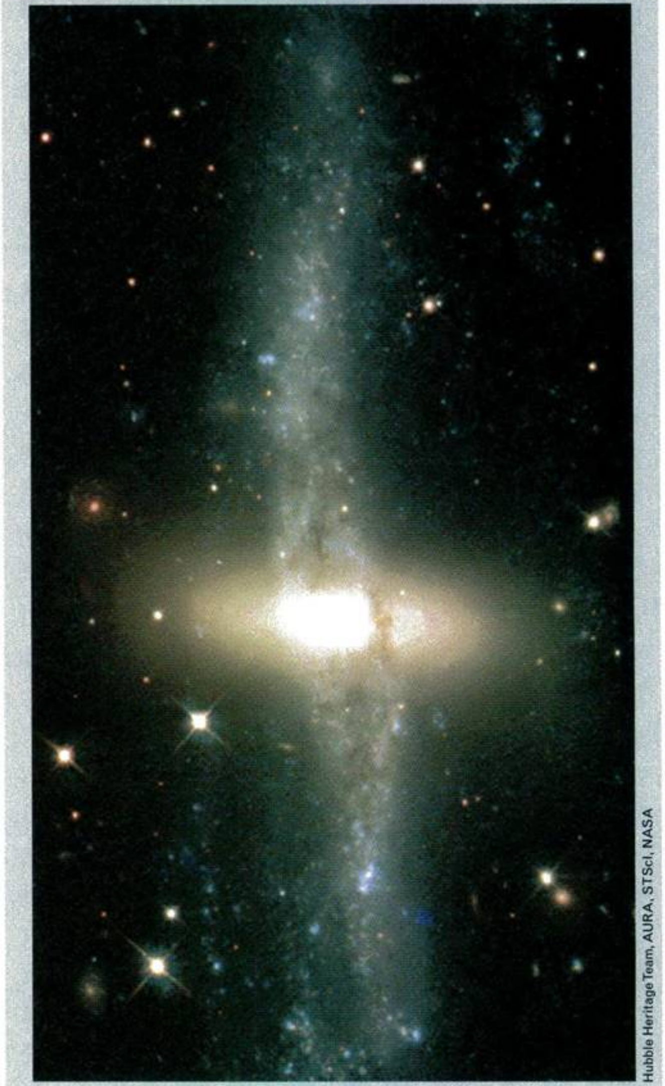


Spring squalls on Uranus

7,900-mile storm on Saturn

J. Bell (Cornell U.), S. Lee (U. of Colorado), M. Wolff (SSI), and NASA

PEOPLE'S CHOICE



Hubble Heritage Team, AURA, STScI, NASA

THE "POLAR-RING" GALAXY NGC 4650A was dubbed the people's choice after a vote by 8,000 Internet users indicating they wanted the Hubble Space Telescope to photograph it. Located about 130 million light-years away, the object is one of 100 known polar-ring galaxies. Astronomers don't know how the unusual disk-rings form, but one possibility is that they are the remnants of colossal collisions between two galaxies in the distant past, probably at least 1 billion years ago. During the collision, gas from the smaller galaxy would have been stripped off and captured by the larger galaxy, forming a new ring of dust, gas, and stars, which orbit the inner galaxy almost at right angles to the old disk. Hubble's Wide Field/Planetary Camera 2 captured the nearly edge-on ring using color filters that transmit blue, green, and near-infrared light.

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Northern Lights Tour

Alaska
March 3-12, 2000

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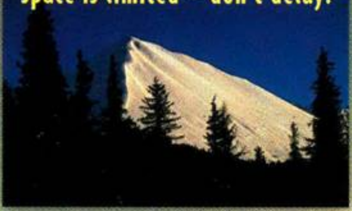

Chase the colorful curtains of the aurora borealis through Alaska's interior with *Astronomy* Magazine. Along with catching one of the most spectacular views of the night sky, you will experience the magnificent vistas of a great, unspoiled wilderness.

Our adventure begins in Chena Hot Springs, 60 miles from Fairbanks and far from light pollution. The evening aurora should produce an impressive show as solar activity is expected to be high in March 2000. During the day, you can take advantage of cross-country skiing, snow shoeing, and ice skating. Or relax in the world-famous hot springs.

The trip concludes with five nights in Fairbanks, one of Alaska's major urban centers that still maintains a pioneering spirit. You can arrange to shop, downhill ski, attend the Ice Festival, or simply curl up with a good book.

The breathtaking scenery is guaranteed to put you on sensory overload. Whatever your choices for the daylight and evening hours, pack your warm clothes and join *Astronomy* on this watch for the magical northern lights in the heart of Alaska. See you there!

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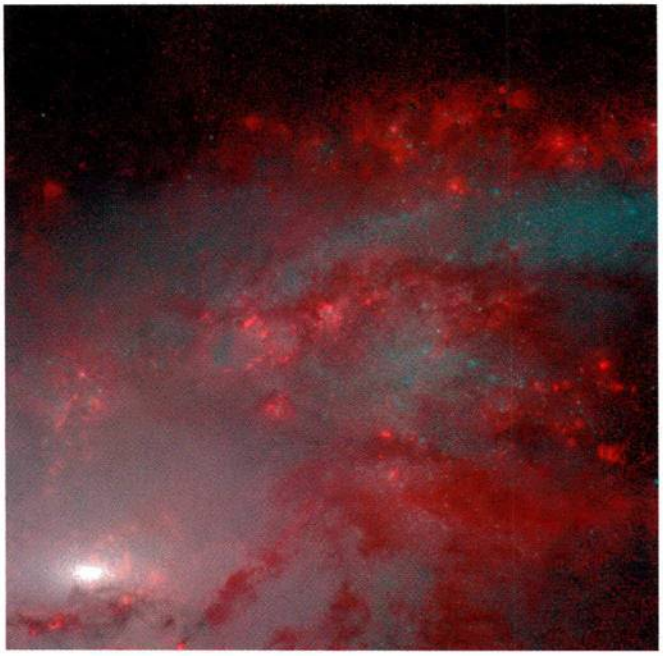

Jim Herrnstein, NRAO

A radio astronomer estimated that Earth is about 4 light-years closer to this galaxy, M106, than previously thought.

COSMOLOGY

Estimate of the Universe's Age Dips 15 Percent

▶ Astronomer Jim Herrnstein has found what he thinks is a significant flaw in an exhaustive eight-year Hubble Space Telescope study. During a May news conference in Washington, D.C., the Hubble team said that the age of the universe is about 13.5 billion years, plus or minus 10 percent. However, Herrnstein says the universe could be 15 percent younger than that.

The discrepancy is based on the way astronomers generate standard-distance yardsticks to estimate the universe's age. The Hubble team, conducting what it calls the Key Project, used the luminosities of variable stars in 18 nearby galaxies — an indirect method — to generate its distance yardstick. Herrnstein, of the National Radio Astronomy Observatory in Socorro, New Mexico, used the Very Long Baseline Array, a system of radio telescopes from Hawaii to the Virgin Islands, and a simple trigonometry formula. He found that bright blobs of gas called water masers traveling 2.4 million miles per hour moved by a tiny angle (0.1 milliarcsecond) from 1994 to 1997. He used the speed of the water masers and the angle that they moved across the sky to compute the distance from Earth of galaxy M106 (NGC 4258).

The Hubble group reported the galaxy is 26.7 to 29.0 light-years from Earth while Herrnstein estimated that it was only 23.5 light-years, plus or minus 1 light-year.

Herrnstein, who announced his results at the annual meeting of the American Astronomical Society in June, said there are uncertainties in his method, but those uncertainties are less than those reported at the May news conference by Key Project leader, Wendy L. Freedman. "I am skeptical that the Key Project has achieved its goal," he says.

Freedman, who attended an AAS news conference in June at which Herrnstein spoke, was surprised by his results. She said that Herrnstein's findings are "wonderful," calling them "a big step forward in distance measurements."

METEOR SHOWER

Leonid Stream Is Braided

▶This year's Leonid meteor shower will peak during the evening of November 17 in the United States. Scientists say the estimate is more reliable than predictions for last year's shower, which were off by 16 hours. The annual Leonid light show is made possible by a dense arc-shaped cloud of particles shed by Comet Tempel-Tuttle during its 1333 appearance.

David Asher and Mark Bailey of Armagh Observatory and Vacheslav Emel'yanenko of South Ural University reported in a recent letter to the Royal Astronomical Society that the arc of particles left behind by the long-period comet is braided like a rope. Each particle in the braid orbits the sun in a stable "resonance" orbit that prevents Jupiter from devouring it.

"This work demonstrates the highly complex structure of Halley-type cometary meteoroid streams and is the first observational proof of the importance of orbital resonances in the structure of a well-known meteor shower," says Bailey.

In a related development, Martin Beech and Simona Nikolova of the University of Regina, Saskatchewan, Canada, have found evidence for basketball-size meteoroids in the Lyrid stream. The April Lyrids were first noted in 687 B.C., making them the oldest recorded meteor shower. The April 22, 1803, storm offered the most spectacular Lyrid show in recent times in the eastern United States with a maximum rate of about 900 meteors per hour, including many large fireballs.

— ANDREA GIANOPOULOS

Arthur Scott Murrell

This year's Leonid meteor shower will peak over the United States the evening of November 17.

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For Jaw-Dropping Views of the Heavens

New!

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A Big Step Up from the Competition's Rolled Paper Tubes

New!

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Friction Optimization Eliminates Balance Woes, Improves Gliding Motion

New!

Huge, Deluxe Accessory Package Included!

- *TWO Plössl Eyepieces*
- *6x30 Finder Scope*
- *Eyepiece Rack*
- *Moon Filter*
- *Snap-On Dust Cap*
- *Astronomy CD-ROM*

6
8
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BETELGEUSE

A Favorite Supergiant Gets Even More Popular

▶ Astronomers are drawn to objects that are big, nearby, and bright. That is why Betelgeuse, a red supergiant star about 430 light-years away, has become a darling. Groups of astronomers working independently of each other have recently used the most powerful space and ground-based telescopes to discover new features of Betelgeuse, our closest red supergiant.

For instance, the star's enormous body of boiling gas — fueled by nuclear fusion in its core — would extend to Jupiter's orbit if it were substituted for the sun.

A team of astronomers at New Mexico's Very Large Array also discovered that plumes of convection circulate between Betelgeuse's surface and its atmosphere. "To our surprise," says Stephen White of the University of Maryland in College Park, "the images show that most of the gas in the atmosphere is only about as hot as that on the surface. Previously, all of it was though to be very much hotter."

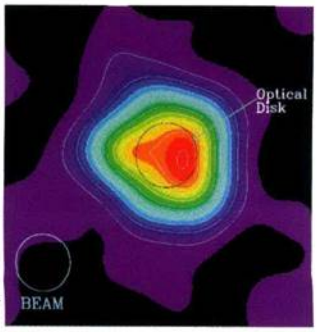
Using the Hubble Space Telescope, scientists at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, show that the star's gassy emissions extend twice as far as previously thought. In addition, a team of astronomers led by Han Uitenbroek analyzed the bright spots on Betelgeuse's surface and concluded that they are not a result of convection. On the contrary, observations suggest that the star's rotation, which takes about 17 years to complete, modifies energetic shock waves and creates a signature in the atmosphere marked by a bright spot.

Not every scientist looking at Betelgeuse is interested in it as a model for other red supergiants. A team of astronomers at the University of Arizona's Center for Adaptive Optics used a technique called nulling interferomtery to look for planets or anything else orbiting it. The technique selectively eliminates the star's bright glare so astronomers can pick out fainter nearby objects — if they exist.

University of Arizona astronomer Phil Hinz and his team turned the Multiple Mirror Telescope on Betelgeuse. Software cancels out starlight received by each MMT mirror, revealing a faint dust cloud surrounding the star — but no planet. While the dust cloud had been discovered by other astronomers, the interferometry technique provided the first direct image of the thin cloud. If the interferometry technique is applied to a star with planets orbiting it, planets that otherwise would be hidden by the star's glare could be visible.

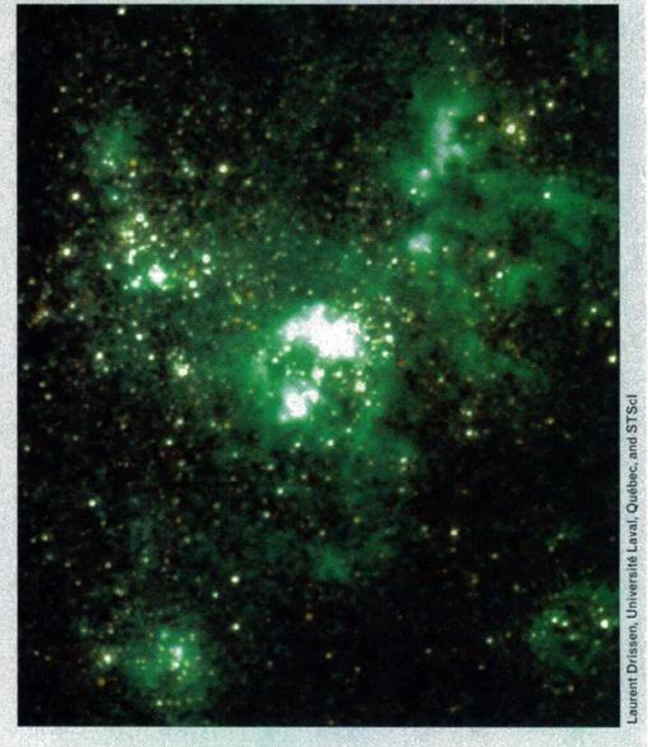
— Tracy Staedter

This false-color radio-telescope image of cool (5,000° C) gas enveloping Betelgeuse is twice the size of hotter gas (black circle). The white circle, bottom left, shows the Very Large Array's angular resolution of 40 milliarcseconds.



Ralph G. Marson, NRAO

STAR BIRTH



Laurent Drissen, Université Laval, Québec, and STScI

SPIRAL GALAXY NGC 2403 contains a variety of objects that were captured by the Hubble Space Telescope's Wide Field/Planetary Camera 2: bright red supergiants, intensely hot Wolf-Rayet stars discharging clouds of dust, and gas clouds giving rise to newborn stars. Wolf-Rayet stars and young blue stars form the cores of bright clusters, while red supergiants are distributed in an extended halo. The brightest of the pictured clusters (center) is 3.5 to 5 million years old. This new observation provides evidence for two star-forming events because the presence of red supergiants indicates that massive star birth was occurring as recently as 7 to 10 million years ago. NGC 2403, in Camelopardalis, is a member of the M81 group of galaxies.

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Could a Nearby Burst Scorch Earth?

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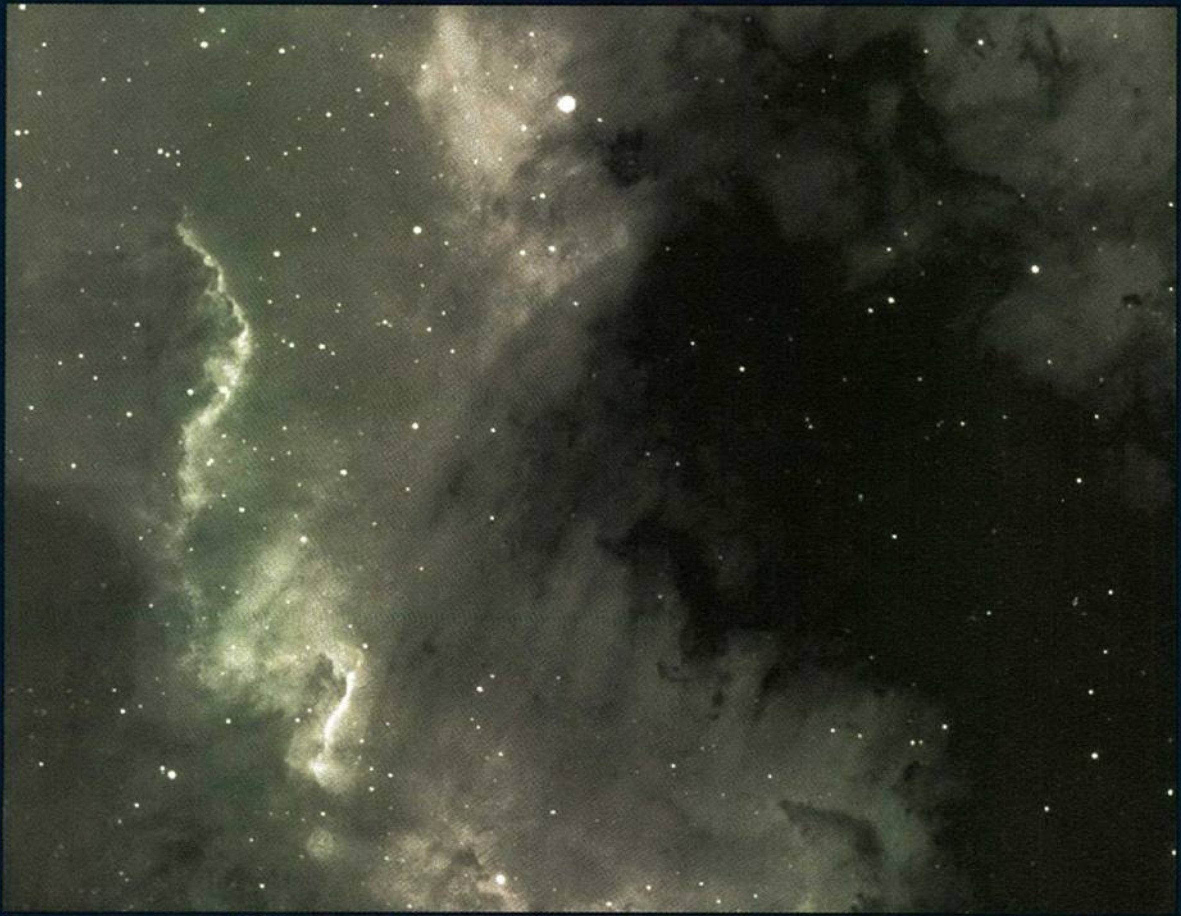

Amateur astronomer Brad Ehrhorn captured this beautiful false color image of NGC7000, The North American Nebula, through a 5" f/6 Takahashi refractor using an SBIG ST-8 CCD camera equipped with an H-alpha Filter.

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were remnants of two distant supernovae indicate that the original explosions were 100 times more powerful than that produced by supernovae. The two explosions in the galaxy M101 will be reclassified as hypernovae, ultra-luminous blasts of energy that can momentarily outshine the rest of the universe. The discovery has led some scientists to propose that hypernovae may even cause enigmatic gamma-ray bursts (GRBs).

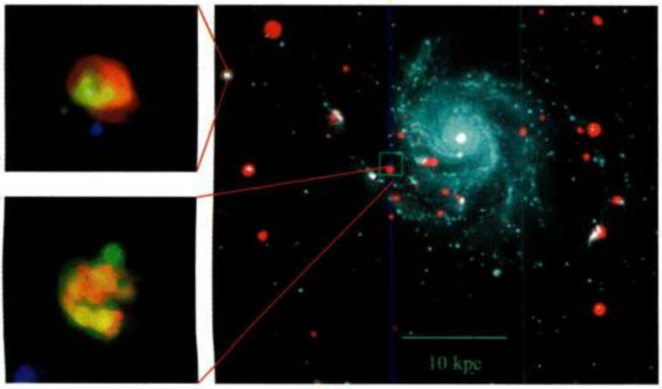
Q. Daniel Wang of Northwestern University calculated that the remnants are highly energetic. "A supernova is believed to form a neutron star," he says. "A hypernova is believed to form a black hole, presumably from a very massive star's collapse."

One nebula, MF83, one of the largest known supernova remnants, is more than 860 light-years across and about 1 million years old. The second remnant, NGC 5417B, is only 30,000 years old and is expanding at 100 miles (160 km) per second. Each remnant is 10 times more luminous in the x-ray spectrum than any of the most brilliant supernova remnants in our own galaxy.

Could a gamma-ray burst caused by a hypernova occur in the Milky Way Galaxy? "Yes," says Wang. "In principle, a hypernova could occur anywhere in any galaxy." And if one did explode in our galaxy, we would probably be able to view it with the naked eye. The discovery is expected to lead to searches for other hypernova remnants or stars with the possibility of ending in hypernova blasts. "In our galaxy, the best candidate is the star Eta Carinae," Wang notes. Eta Carinae is a rare type of star called a luminous blue variable. It is 8,000 light-years away, close enough for a good show, but far enough from us not to harm Earth should it explode as a hypernova.

What could happen to life on Earth if a hypernova or gamma-ray burst occurred significantly closer than Eta Carinae? The astronomer who made the visible-light observations of the remnants, You-Hua Chu of the University of Illinois, says, "You'd be baked — roasted." But the odds are on our side. "A hypernova occurs only under very rare circumstances," explains Wang. "The chances are very small that a hypernova would occur so close to the solar system." — Kelly Whitt

Spiral galaxy M101 has two nebulae that may have originated from hypernovae: NGC 5471B, upper left, and MF83, lower left.



Y. Chu (UIUC), POSS, ROSAT, MDM, HST

18th Moon of Uranus Found in Old Photo

Erich Karkoschka, a scientist carefully examining 13-year-old images taken by the interplanetary spacecraft Voyager 2, discovered an 18th moon orbiting the planet Uranus, the International Astronomical Union announced May 19. Saturn had been the only other planet in our solar system known to have as many as 18 satellites. The satellite of Uranus was discovered this year but is designated Satellite 1986 U 10 (or S/1986 U 10), because its discovery was based on Voyager images taken in 1986. "This discovery is very unusual," says Karkoschka, a researcher at the University of Arizona's Lunar and Planetary Lab in Tucson. "Typically, satellites are found within days after the discovery image has been taken. In this case, the discovery image is more than 13 years old." For more, go to http://www.astronomy.com/horizon.html.

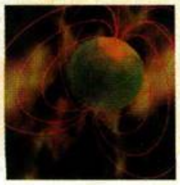
The newly discovered moon, S/1986 U 10, is too dim to see in this image of Uranus taken by Voyager 2 in January 1986. Erich Karkoschka, University of Arizona, NASA

Scientists Find Cool, Red 'Methane Dwarfs'

Scientists working on the Sloan Digital Sky Survey have found two reddish objects — methane dwarfs — which float free in space rather than orbiting a star. The reddish color and the presence of atmospheric methane are significant because they indicate the the objects are cooler than other brown dwarfs, the only other known objects in the same mass range. One of the methane dwarfs is in the constellation Ophiuchus, the other is in Virgo. The first brown dwarf, Gliese 229B, was discovered in 1995 orbiting the star Gliese 229A. The discovery of methane dwarfs intrigues scientists and raises the possibility that they may be common in the Milky Way Galaxy. For more, go to http://www.astronomy.com/horizon.html.

Magnetic Fields May Not Spark Outbursts

Some astronomers are attacking the "magnetar theory," which holds that colossal magnetic fields trigger brief bursts of gamma and x-ray radiation a million times more powerful than the sun's. New observations of these extremely dense neutron stars indicate that their outbursts may be due to particles ejected by the objects. For more, go to http://www.astronomy.com/horizon.html.



Scientists question whether so-called magnetars have magnetic-field strengths 10^{15} times stronger than those of the sun. Robert Mallozzi/Univ. of Alabama, Huntsville/NASA

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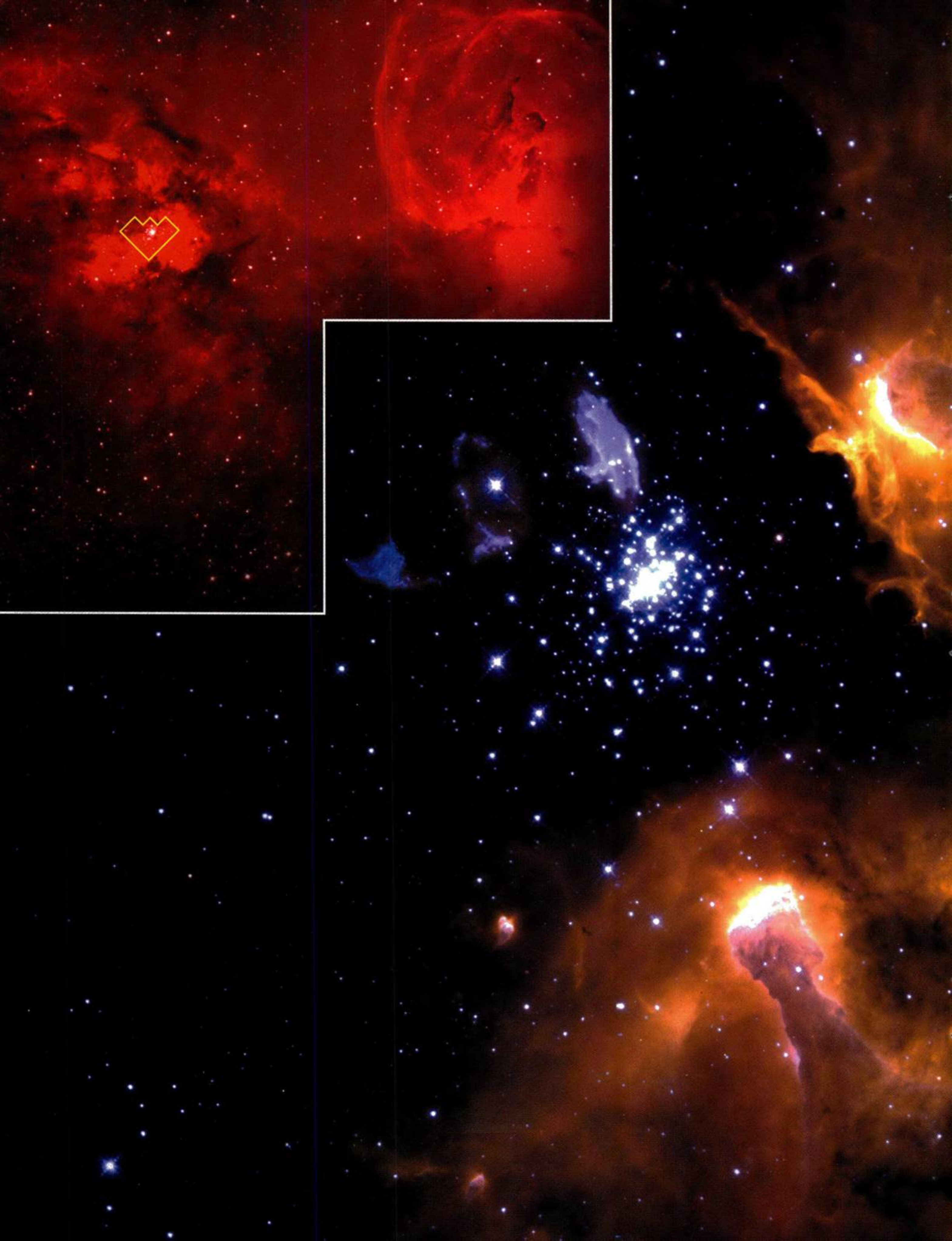


the BEGINNING and the END

In one shot, Hubble captures the progression of stars from cradle to grave.

In this age of increasing specialization in science, astronomers often take a picture to study one particular object or phenomenon. But this new visible-light image from the Hubble Space Telescope's Wide Field/Planetary Camera 2 provides an exception. In one fell swoop, Hubble provides a dramatic view of stars at various stages of their life cycles, from stellar newborns to a star on the brink of disaster.

The false-color Hubble image, taken on March 5, 1999, shows the large star-forming nebula NGC 3603, located 20,000 light-years away in the southern constellation Carina. A ground-based image of NGC 3603 appears at the upper left.

A cluster of 10,000 hot, newborn stars — crammed into a sphere only 6 light-years wide — dominates the center of the Hubble image. The largest stars in this cluster contain 100 times more mass than the sun and shine with the intensity of 1 million suns. Despite a tender age of 1 million years, the most massive stars are burning their nuclear fuel so rapidly that they are already halfway through their life cycles.

To the upper left of the cluster lies the blue supergiant star Sher 25, which contains the mass of about 25 suns. It formed some 15 million years ago and will explode within 100,000 years, shining as bright as a 1st- or 2nd-magnitude star as seen from Earth. Sher 25 is surrounded by a 1.3-light-year-diameter equatorial ring of glowing gas that is very similar to a ring surrounding Supernova 1987A. In both cases, a companion star might have spiraled into the primary star when the primary expanded into a red supergiant, and this interaction formed a ring. Sher 25 is ejecting nitrogen-rich gas along its poles, which shows up as glowing, blue blobs to the lower left and upper right of the star.

Two gaseous pillars are clearly visible beneath and to the right of the cluster. Stars are forming inside these structures, which are virtual copies of the "elephant trunks" of the Eagle Nebula. These pillars are being slowly eroded by the combined radiation of the cluster's stars. "If we looked a million years from now, the pillars would be gone," says Wolfgang Brandner of the Jet Propulsion Laboratory, a co-investigator on the team that took the Hubble image.

Several Bok globules (named after Dutch astronomer Bart Bok) can be seen at the far upper right. These dark, compact clouds are less than a *light*-year across. The dust in each globule is probably obscuring between one and three newborn, low-mass stars.

The bright, gaseous shrouds of two protoplanetary disks can be seen near the bottom center of the image. Radiation from the cluster's stars is heating the disk material, literally destroying the disks from the outside in, probably before they will have a chance to form planets. "This is an unhealthy place. Our solar system couldn't have formed in such an extreme environment," says Brandner. — *Robert Naeye*

Left: A cluster of 10,000 hot, young stars dominates the center of this Hubble Space Telescope image of NGC 3603. Wolfgang Brandner (JPL), Eva Grebel (University of Washington), You-Hua Chu (University of Illinois), and NASA

Upper left: This ground-based telescope image of NGC 3603 is closer to true color than the Hubble field (boxed in yellow). Sean Points (University of Illinois) and Chris Smith (CTIO)

Give PEAS a CHANCE

Could an exotic object known as a pea instanton have given birth to our universe?

by Tom Yulsman

IN THE BEGINNING, there was the singularity — that mind bogglingly small point of Brobdingnagian density that put the BANG in the Big Bang.

Or was there?

The singularity is what you'd see if the classic movie of the Big Bang and subsequent cosmic evolution were run in reverse to the opening frame. All the planets, all the stars, all the galaxies, all the intergalactic gas and dust, in short, all the matter and energy in the universe, would zoom backward in time and converge into an infinitely tiny, infinitely dense — and singularly unexplainable — speck. Here, all the laws by which scientists explain nature would break down.

As a theory of cosmic evolution, the Big Bang is remarkably successful. But it rests on the deep enigma of the singularity, and for scientists, an explanation for creation built on the unexplainable is just not satisfying.

"The problem we have is that every particle in the universe originated in the singularity," says Neil Turok, a mathematical physicist at Cambridge University in England. "That's unacceptable because there are no laws of physics that tell you how they came out of it."

And so scientists are seeking to refine their explanation of the ultimate origin of the universe.

"Many cosmologists are now asking the deeper questions of how the universe really began," says Alan Guth, a cosmologist at the Massachusetts Institute of Technology. "What *started* the Big Bang?"

The hunt for an answer grew more interesting in 1998, when Turok and his Cambridge colleague, Stephen Hawking, announced they had found a way to sidestep the singularity, if not eliminate it. In the process, they said they had arrived at a compellingly simple and complete explanation for how the universe began.

Well, not precisely. In Turok and Hawking's mind-bending creation model, the universe has no discrete beginning. Instead, the scientists propose a quantum theory of the origin of the universe in which there is no distinction between time and space, and no distinct point at which either can be said to begin.

If all that seems a bit much to wrap your neurons around, consider the microscopic primordial object within which Turok and Hawking say this blending of space and time occurred. They call it a "pea instanton." And what an extraordinary pea it is, for Turok and Hawking insist that it's the seed from which the universe sprouted. They boldly argue that not only do all the laws of physics work just fine within their instanton, but those laws actually imply its existence.

Turok and Hawking's pea instanton is attractive as a scientific theory because it can be tested. The theory makes specific predictions about the nature of the universe that sprouts from the instanton — predictions that other scientists can check by seeing how accurately they match the universe we actually live in.

"One can predict everything about the universe from this initial instanton," Turok says. "The calculations are very precise."

But of course, precision doesn't guarantee truth. And some skeptical cosmologists question whether the pea instanton really is getting at some universal truth.

Stanford University cosmologist Andrei Linde dismisses the instanton as a mathematical abstraction with no clear basis in reality. Moreover, he questions whether it's even possible to explain how the universe could have been created from nothing.

"Stephen is an extremely talented person," Linde is careful to say of Hawking. "Sometimes, however — this is my interpretation — he trusts mathematics so much that he makes calculations first and interprets them later." Linde finds this trust in the primacy of the math to be a bit like religious faith.

"You know, it is such an esoteric science, creation from nothing. You

Cosmologists believe that the laws of physics led to a universe of near-infinite complexity.

Image of NGC 5090 and 5091 by European Southern Observatory

Neil Turok

"One can predict everything about the universe from this initial instanton. The calculations are very precise."

can come away with your interpretations and there is no way to check them. It is like a religion."

But mathematical abstractions have been Hawking's stock in trade. And this certainly wouldn't be the first time that one of his ideas has met with initial incredulity only to gain support over time. (Although it's also true that some of Hawking's abstractions have not checked out.)

THE BANG IN THE BIG BANG

Despite the enigma of the singularity, the big bang theory is unquestionably one of the most successful ideas in the history of science. It precisely predicted, for example, the relative amounts of the two most abundant elements in the universe, hydrogen and helium. It also successfully predicted that the universe would be filled with microwave energy, dubbed the cosmic microwave background radiation — the fading echo of the big bang explosion. And the theory neatly explained why today's universe is expanding: The motion is a relic of the Big Bang's explosive beginnings.

But where did all the matter and energy in the universe come from, and what really put the BANG in the Big Bang? The theory actually does not say. In fact, contrary to common belief, the Big Bang does not explain the origin of the universe. It doesn't even explain a bang. Something had to happen *before* the Big Bang to get it going.

"Although the classical cosmological theory is called the Big Bang, the theory in fact contains no description whatever of the 'bang,'" Guth is fond of saying. "It proposes no answer at all to the question of what banged, how it banged, or what caused it to bang. It is really a theory of the aftermath of a bang."

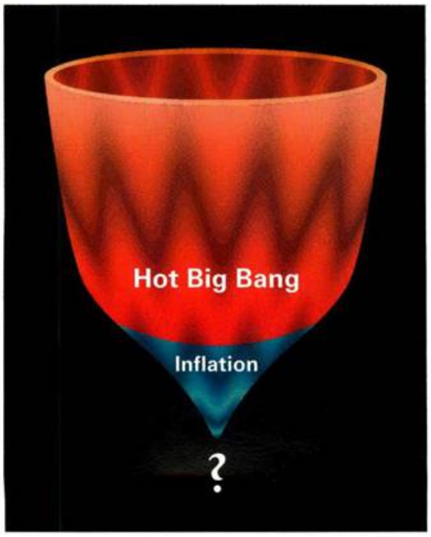
The big bang description of creation, Guth says, simply begins with a cosmic fireworks display already in progress — a fireball of outrushing radiation and particles.

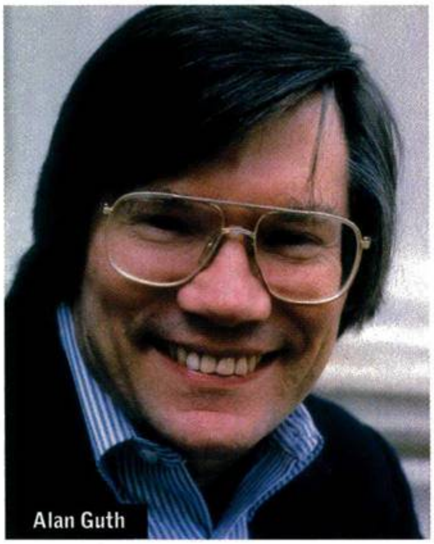
It was Guth himself who offered the first compelling explanation for what ignited the fireball. In 1981, he published a paper suggesting that the infant universe experienced a bout of gargantuan inflationary growth. The physics of this inflationary universe theory, as it came to be called, is so far-reaching that it explains in one stroke how the big bang universe arose, how matter was created, and why the universe looks the way it does in several fundamental ways.

As a particle physicist at the Stanford Linear Accelerator Center in the late 1970s, Guth never imagined that he would wind up making a profound contribution to the field of cosmology. But while at Stanford, Guth found himself working on a problem that lay at the intersection between the two scientific fields.

Guth was focused on the incomprehensibly tiny and hot patch of space-time that was the early universe.

In the inflationary model, a very short period of extraordinarily rapid expansion just after the birth of the cosmos gives rise to the hot big bang universe we live in.





Donna Coveney/MIT

"The big bang theory proposes no answer at all to the question of what banged, how it banged, or what caused it to bang."

There would have been no matter as we know it today in this patch — space-time would have consisted of a vacuum — yet the vacuum was not really empty. Like a cloth billowing in the wind, the fabric of space-time in a vacuum actually is roiled by quantum fields.

As Guth knew, the grand unified theories of particle physics predicted that the vacuum of the early universe would have been dominated by particularly energetic fields. As these "scalar" fields fluctuated, their potential energy would have risen and fallen. Guth realized that it was theoretically possible for the potential energy of the fields to have gotten temporarily "stuck" at a high value. Admittedly, this was an assumption. But when Guth worked through its implications, he stumbled onto inflation.

His calculations showed that stuck scalar fields would have caused a tiny bubble of "false vacuum" to nucleate from the primordial patch of space-time. The amazing thing about the bubble, Guth saw, was that it would have contained a huge amount of antigravitational energy. Although this idea may seem unbelievable, it's actually in accord with standard particle theories. Here's how it works:

Since an ordinary vacuum contains energy in the form of quantum fields, gravitational energy must be present as well. To understand why, it helps to remember Einstein's famous equation, $E=mc^2$. According to the equation, energy ("E") and mass ("m") are really two forms of the same stuff. So if matter exerts a gravitational pull, so must energy. In other words, the energy-containing quantum fields of an ordinary vacuum exert a gravitational pull, albeit a weak one.

But when Guth used Einstein's relativity equations to see what would happen inside a bubble of false vacuum, he found that the gravitational energy would have the opposite effect of ordinary gravity. In other words, this gravity would push, not pull — it would, in essence, be a powerful source of antigravity.

Starting out as small as one-billionth the size of a proton, the initial bubble of false vacuum would have been propelled by this antigravity into an incredibly brief period of exponential growth. By one reckoning, in just 10^{-35} second, the bubble would have grown to the size of a basketball. (Some models of inflation predict that the universe would have grown much larger than that.)

The bubble of false vacuum would have had another peculiar property as well. According to particle theory, as the bubble expanded, the density of the energy within it would have remained constant. To picture this, imagine an inflating balloon. If the density of air inside is to be maintained, the total amount of air must be increased. Similarly, to maintain the same density of energy within the expanding bubble, the total energy must increase — and by a huge amount because the inflating bubble is growing exponentially.

INFLATION TO THE RESCUE

Eventually (meaning in a very tiny fraction of a second), the false vacuum would have decayed, Guth realized. As this happened, the enormous energy that had accumulated within the false vacuum would have been released suddenly, creating an exploding fireball of radiation and hot particles.

"Inflation," Guth thus concludes, "supplies the beginning to which the standard big bang theory is the continuation."

But inflation theory does much more than explain where the fireball came from. It also explains a fundamental quality of our universe that's beyond the scope of the standard big bang theory. In short, observations show that the texture of the cosmos is smooth overall but lumpy at smaller scales. The smoothness is evidenced by the cosmic microwave background radiation, which appears to be at almost exactly the same temperature throughout the cosmos. Yet any look through a powerful telescope reveals the lumpiness amidst this homogeneity: galaxies, clusters, and superclusters.

According to inflation theory, prior to the bout of exponential growth, the contents of the universe were packed together into an exceedingly tiny space — close enough for everything to come to a uniform temperature and density. (In the big bang theory, the contents of the universe were too loosely packed for this to happen.) Then, as the universe inflated, quantum fluctuations spontaneously wrinkled the fabric of space-time.

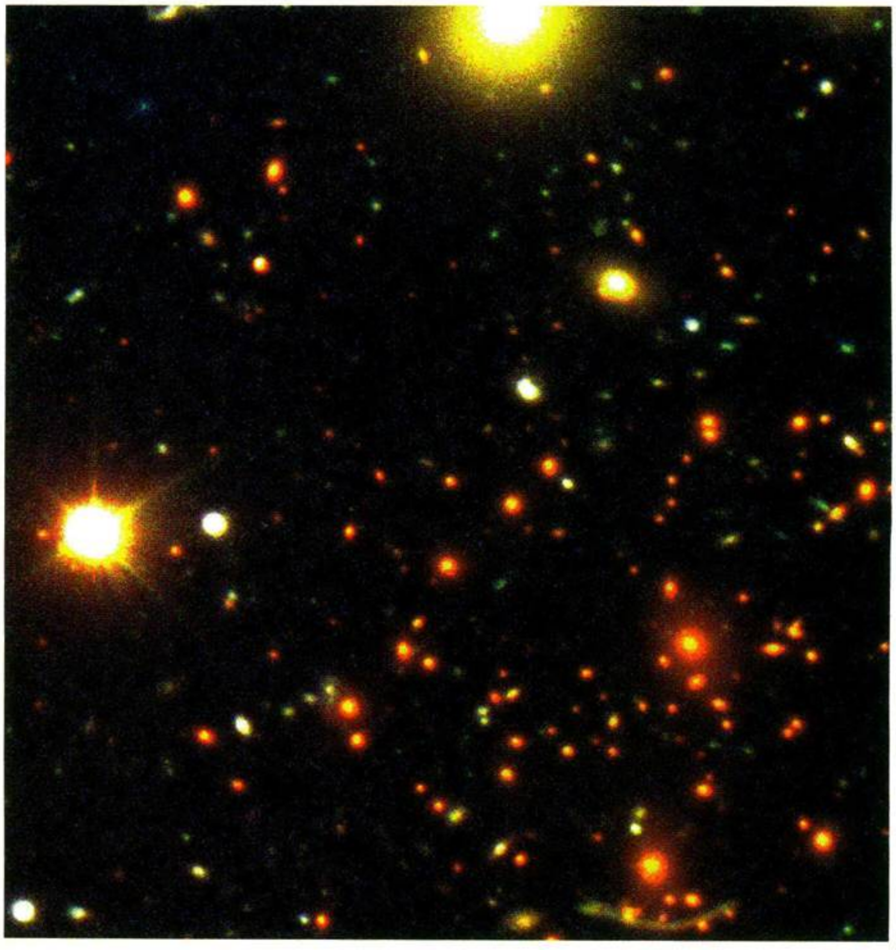
These wrinkles were almost instantly stretched to enormous size by inflation and thereby ironed permanently into the warp and woof of the universe. After inflation, the imperfections formed regions of slightly higher gravity on an otherwise remarkably homogeneous background. This caused matter to coalesce into the galaxies and clusters that punctuate the uniformly cold and dark cosmic background like a diamond necklace glittering against a black dress.

Most models of inflation make another significant prediction, but one that has not yet been borne out conclusively by astronomical observations: The geometry of space-time should be flat.

If observations show otherwise — if they show that the cosmos is curved even slightly into an "open" geometry — then either the theory is wrong or scientists will have to find a way to alter it so inflation can produce an open universe.

It may be difficult to imagine curved space, but remember that Einstein told us that both matter and energy exert a gravitational pull by bending space-time into a kind of well. So comets plunge toward the sun because they are "falling" into our star's gravity well.

The geometry of the universe is determined by the density of matter within it. If the universe were open, the



Inflation turned tiny wrinkles in the fabric of space-time into seeds of huge galaxy clusters.

Image of galaxy cluster Abell 370 by ESO

Image of NGC 6872 and IC 4970 by ESO

As currently understood, the pea instanton would create such a low-density universe that interacting galaxies could not exist.

density of matter would be too little for the collective force of gravity to overcome the kinetic energy of outrushing matter as the universe expanded. In this case, the ratio of gravitational to kinetic energy, a term called "omega," would be less than 1. The resulting open geometry would be something like a horse's saddle, and the universe would continue expanding forever.

In the flat universe predicted by most models of inflation, the cosmos would be perched precariously between an open geometry and a closed one (in which the density of matter would be high enough to overcome the universe's expansion). Omega would have to equal 1 to within one part in 100,000, meaning that gravity and expansion would be, for all intents and purposes, equal. In this case, the universe would continue expanding forever; the expansion would forever slow and ultimately approach zero.

Inflation predicts flatness because regardless of the shape of the infant universe, the enormity of the expansion would drive the part of the universe we can observe today toward perfect flatness. To understand why, imagine an ant on the surface of an inflating balloon. As the balloon grows to enormous size relative to the ant, the part of the surface the ant can see appears flat, just as Earth's surface seems flat to us.

A FLAT OR OPEN UNIVERSE?

Much to the dismay of inflationary theorists, however, a wide variety of astronomical observations indicates that the density of matter in the universe is somewhere between 50 and 80 percent below that required for flatness (and nowhere close to that required for a closed geometry). Given these numbers, the universe looks quite open.

But just last year, theorists regained hope for a flat universe when new observations showed that the rate of cosmic expansion was accelerating, not slowing as had been expected. If this proves correct, something must be pushing the fabric of space-time apart. And that something, many cosmologists believe, is a theoretical form of energy called the cosmological constant.

Since energy is equivalent to mass, the repulsive energy of the hypothesized cosmological constant must, like any mass, exert gravity. And if there were precisely enough of this gravity, it would balance the books: Although the universe might fall far short of the mass density, and thus gravity, required for flatness, the gravity provided by the cosmological constant would make up the difference.

In other words, the universe would be flat after all, and inflation mavens such as Guth and Linde would smile because observations would be in accord with their theories.

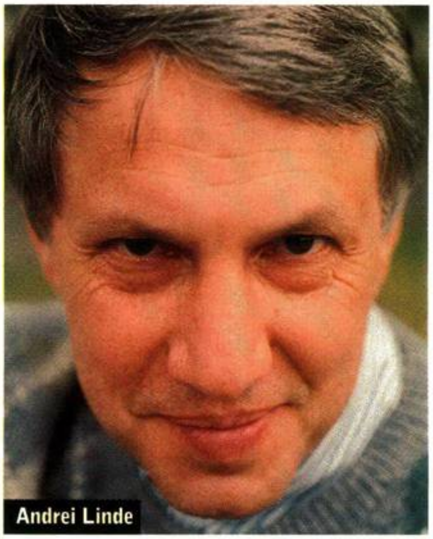
But there are quite a few "ifs" in this scenario, Turok skeptically points out. The new data on cosmic expansion might, in fact, be wrong. And even if the data prove to be right, and a cosmological constant exists, its energy might still add up to an omega less than 1, making the universe open. And that would mean trouble for standard theories of inflation. Which is exactly why Turok and Hawking have been pursuing their theory: The pea instanton, it turns out, produces an open universe through inflation.

There are other complications with inflation as well. For example, in their equations, cosmologists must enter by hand a very precise value for the scalar fields that drive the exponential growth. Without this fine tuning, the scalar fields crash like a breaking wave, and the false vacuum is churned into a frothing mess of true-vacuum bubbles. This picture of the universe looks nothing like our own.

In the eyes of many scientists, such problems haven't invalidated the basic theory. Instead, they've spurred creativity. Cosmologists have proposed a raft of variations on the original inflationary theme, including hybrid inflation, hyperextended inflation, and even "supernatural" inflation.

Perhaps the most profound variation is "eternal inflation," a concept championed by Guth, Linde, and many other cosmologists. Guth explains it this way:

After about 10^{-30} second of inflation, half of the original region of false vacuum would have decayed into a normal vacuum. But that would have left half of the universe still in a false vacuum, meaning it continued inflating. Theoretical calculations (ones that Turok finds quite suspect) show that the rate of this inflation actually would have been much greater than the rate at which the false vacuum decayed. Simple logic therefore dictates that if some areas were inflating much faster than others were decaying, inflation would have outraced decay. And to this day, some part of the universe must be continuing to inflate.


Andrei Linde

CERN Photo

"You know, it is such an esoteric science, creation from nothing. It is like a religion."

In other words, once inflation gets going, it's eternal.

If this is right, we live in a region in which the false vacuum decayed, giving rise to a standard big bang universe. But other areas of the universe must still be inflating. And if a proposal from Linde called "chaotic inflation" is right, there would be still other areas in which inflation never really took off in the first place.

The result would be a gigantic, fractal, multibranching entity called the *multiverse*. In this theory, our universe was born as a tiny bubble of space-time that inflated out of a *pre-existing* region. That region, in turn, inflated out of a previous one, and so on down the line such that the original birth of space-time — the ultimate origin of the universe — occurred so long ago that it may be pointless to ask how it happened.

Our universe would then be but one component of the multiverse, which has been growing through a series of Big Bangs for much longer than our little region of the multiversal whole. And it will continue to grow eternally.

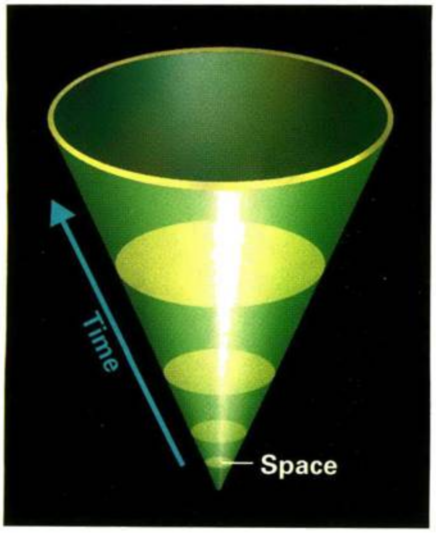
THE ULTIMATE ORIGIN

As powerful as inflation theory seems to be at solving many mysteries of creation, it may still have a fundamental problem at its heart: The dreaded singularity.

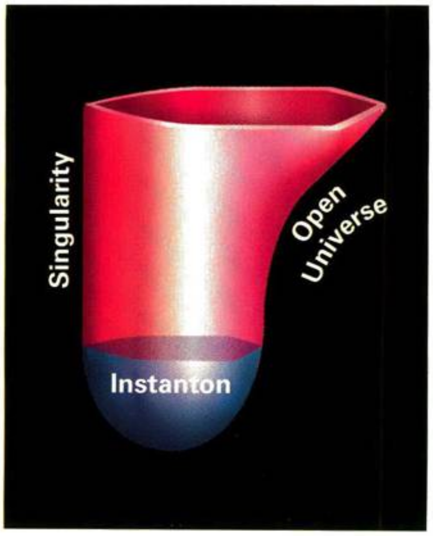
That's why Turok has been searching for an alternative explanation. His search builds on work begun in the early 1980s by Hawking and Jim Hartle, a cosmologist at the University of California, Santa Barbara.

In 1983, Hartle and Hawking used a mathematical approach called the "path integral" to calculate the odds that the universe had begun in a variety of different ways. In a sense, Turok says,

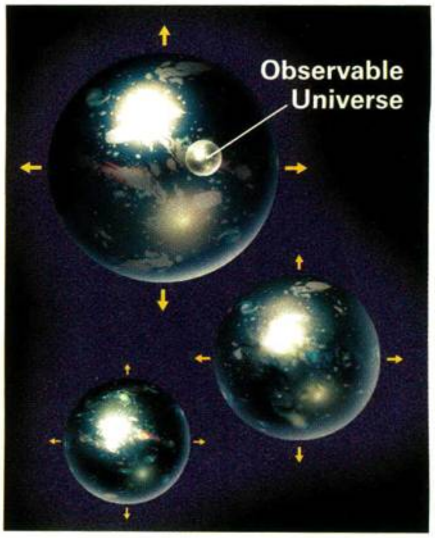
In the no-boundary hypothesis, Stephen Hawking and Jim Hartle envisioned time (depicted here running up the side of a cone) emerging from space (around the cone).



In the Hawking-Turok model, a wondrous object dubbed the pea instanton — which contains a pea's mass jammed into 10^{-30} cm — sprouts into an infinite, open universe.



In the multiverse theory, our universe may be but a tiny part of a vast bubble that inflated out of a pre-existing region. Similar bubbles have been forming since time immemorial.



All illustrations by *Astronomy*: Elisabeth Rowan this approach "uses the laws of physics to define their own starting point."

What emerged was a proposal dubbed the "no-boundary" hypothesis. It can be imagined with a little help from a simple geometric shape: a cone.

Imagine that the cone represents the evolution of the universe. Time runs *up* the side of the cone, while space runs *around* the cone. As you go up (forward in time), the width of the cone (space) enlarges. The origin of time and space is the point at the bottom. In the traditional big bang model, this is the singularity.

But in quantum physics, there is no such thing as a precise point — there is an uncertainty to it. To visualize this, imagine that the point is rounded off. (Picture an extreme blow-up of the tip of a ballpoint pen.) This is just what Hartle and Hawking's path integral predicted as the most likely configuration for the universe at its birth. Rather than the time dimension (up the side of the cone) beginning at a discrete point, it emerges from the space dimension (around the cone). And just as there is no point on the surface of a sphere where one can say the sphere "begins," there is no distinct point on the hemispherical, rounded-off bottom of the cone where time or space begins. There simply is no starting point, and there is no distinction between space and time — or even past and future.

In essence, Hartle and Hawking proposed that the universe inflated out of the bottom of the cone. But there was one problem: Hartle and Hawking could complete their path integral calculations using a class of inflationary theories that produced only a closed universe. Because current observations suggest that the universe is either open or flat, the Hartle-Hawking creation model leads to a different kind of universe than the one we live in.

Stephen Hawking

The White House

Hawking suggested that such a theory might explain no less than the initial conditions of the universe itself.

There the no-boundary idea lay until 1998, when Turok began meeting with Hawking for teatime discussions about models of inflation that could produce an open universe.

Turok had been searching for an open inflation theory since the mid-1990s. Working with Martin Bucher of Cambridge and Alfred Goldhaber of the State University of New York at Stony Brook, Turok and his colleagues had found that a double dose of inflation, in which a bubble universe forms within a bigger bubble, could have done the trick. Strangely enough, calculations show that the space inside the interior inflating bubble, which would correspond to our universe, is geometrically *open*.

But as Turok points out, this scenario is just too "baroque." Moreover, it doesn't describe where the first inflation-driving fields came from (the initial conditions), nor why there necessarily should have been two bouts of inflation.

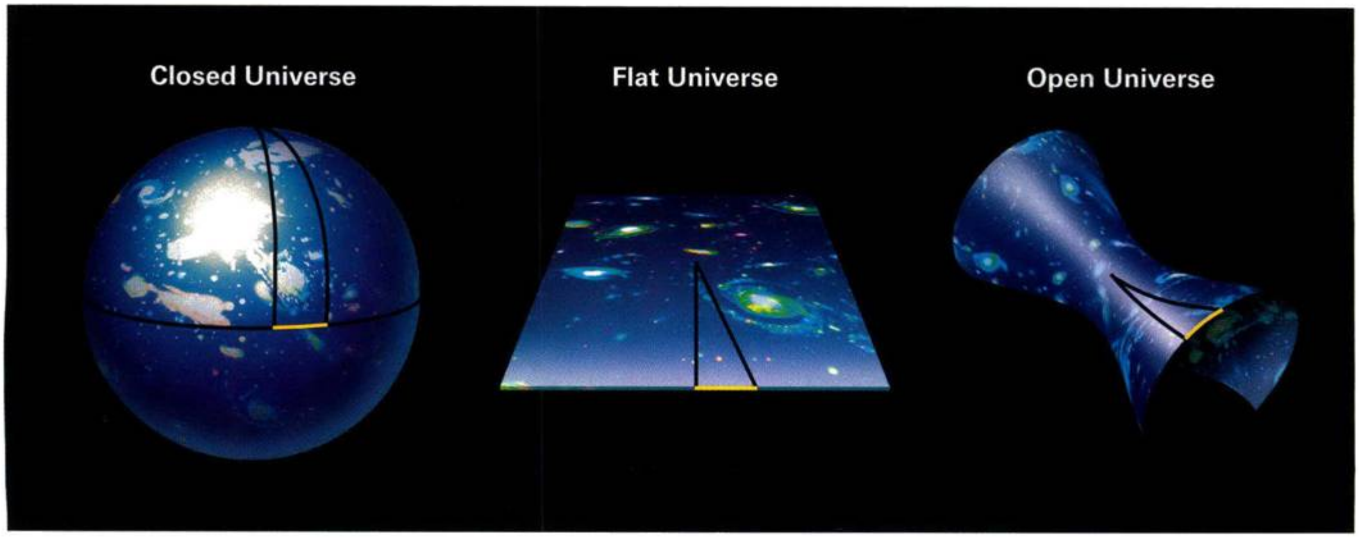
Over tea, Hawking suggested that it might be possible to solve these problems by modifying the no-boundary idea he had developed with Hartle to produce an open bubble universe with only one bout of inflation. Such a theory would vastly simplify things and explain the initial conditions for inflation — meaning no less than the initial conditions of the universe itself.

"This was a genuine surprise," Turok remembers. He decided to take up Hawking's challenge.

Turok's first attempt at a solution was disappointing, he says, because the path integral approach ruled out open inflation from the Hartle-Hawking no-boundary "cone." The reason: Infinite amounts of energy would be produced.

"When I brought this up with Stephen, he said, 'Wait, you didn't include the gravitational energy,' " Turok recalls.

In a flat universe, the angles in a triangle sum to 180°, while in a closed universe they add to more than 180° and in an open universe they sum to less than 180°. Current observations show the universe to be either open or flat.



Once again, since energy is equivalent to mass, energy exerts a gravitational field. Gravity, in turn, has a special feature: Its energy is negative. In other words, infinite positive energy would produce a perfectly balancing infinite negative energy. Crank this into the calculations, Turok and Hawking then realized, and the no-boundary model *would* produce an open, inflating universe — and without any fancy schmancy double inflation. In fact, the path integral calculations showed that such a universe was the *most likely* universe.

NO POD FOR THIS PEA

What does this new creation model look like? Turok and Hawking had imagined it using math. But when Turok attempted to describe the work for an article in the British newspaper *The Sunday Times*, the journalist asked him for a physical description. "You must think of something we can picture," the reporter insisted.

"Well it's small and round, but not perfectly round, and it has little dimples — it's something like a pea," Turok replied.

"The reporter jumped on this and said, 'Okay, it's a pea,' " Turok recalls.

A very special pea to be sure. It's a millionth of a trillionth of a trillionth the size of a normal pea. But it's a lot denser than ordinary matter, so its mass actually is about the same as a pea. Space and time are blended together in the pea such that its "bottom" half is just like the rounded-off tip of the cone in the original Hartle-Hawking no-boundary model. Here again, time emerges from the geometry of space, and there is no discrete beginning to either.

When Turok and Hawking worked out the calculations describing this remarkable creationary object, they found to their astonishment that an open inflating universe instantly (thus the name "instanton") sprouted from the "top" of the pea.

Those little dimples on the surface of the pea that Turok had described to the reporter are there for a reason. They actually are a physical representation of quantum fluctuations that would have ruffled the fabric of space-time. And when the pea instanton sprouts into a universe, these imperfections form a kind of cosmic pattern on which the tapestry of the universe is woven.

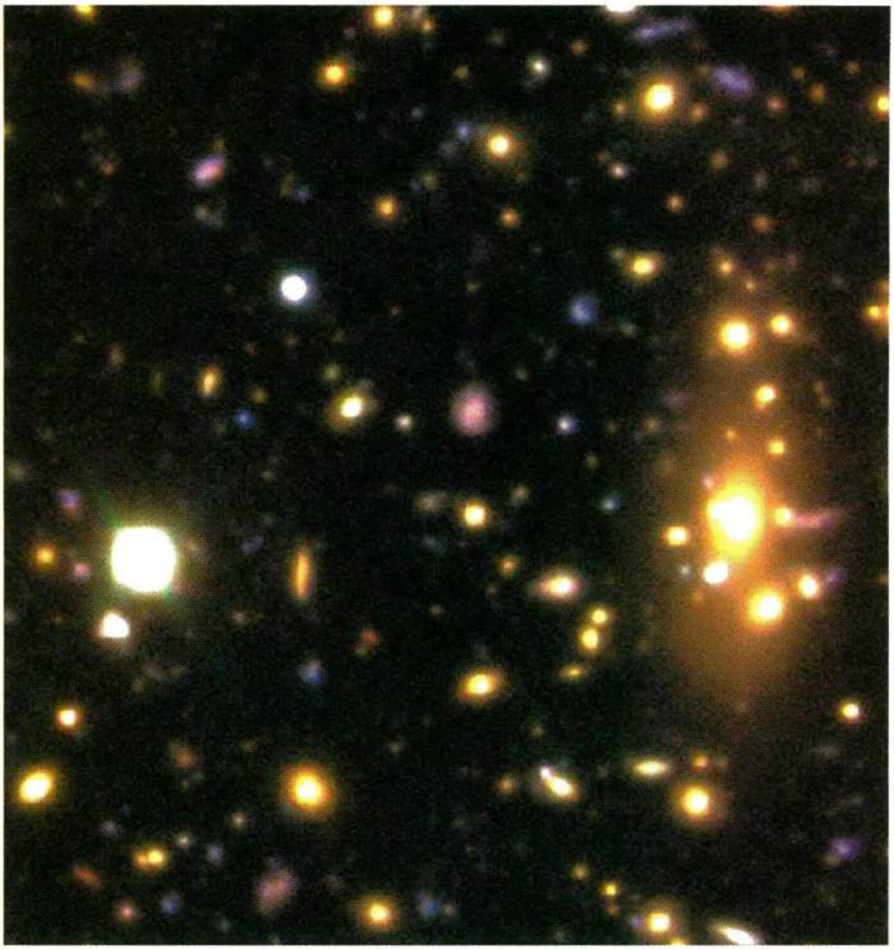


Image of galaxy cluster MS 1008.1–1224 by ESO

Observations of galaxy clusters show that 90 percent of their mass is invisible. Even so, the universe contains too little mass to be closed.

The universe, Turok concludes with wonderment, "all comes out of one formula in a beautiful way."

For Turok, part of the formula's beauty lies in its sheer simplicity and economy. "For sure, I think this is the simplest way for starting the universe," Turok says. And for him and many other scientists, simplicity and economy are major virtues. In fact, as scientists have probed further back in time, closer to creation, they have found that the physics describing the universe at these earlier times gets simpler and simpler.

But the multiverse theory, Turok notes, runs counter to the trend of increasing simplicity in physical explanations for the universe's origin. The multiverse is a profoundly complex entity. In fact, its proponents state that the laws of physics likely would be different in each branch of the tree. This means that it would never be possible to understand how other parts of the multiverse worked — and it would never be possible to derive a single, economical theory of everything, Turok argues.

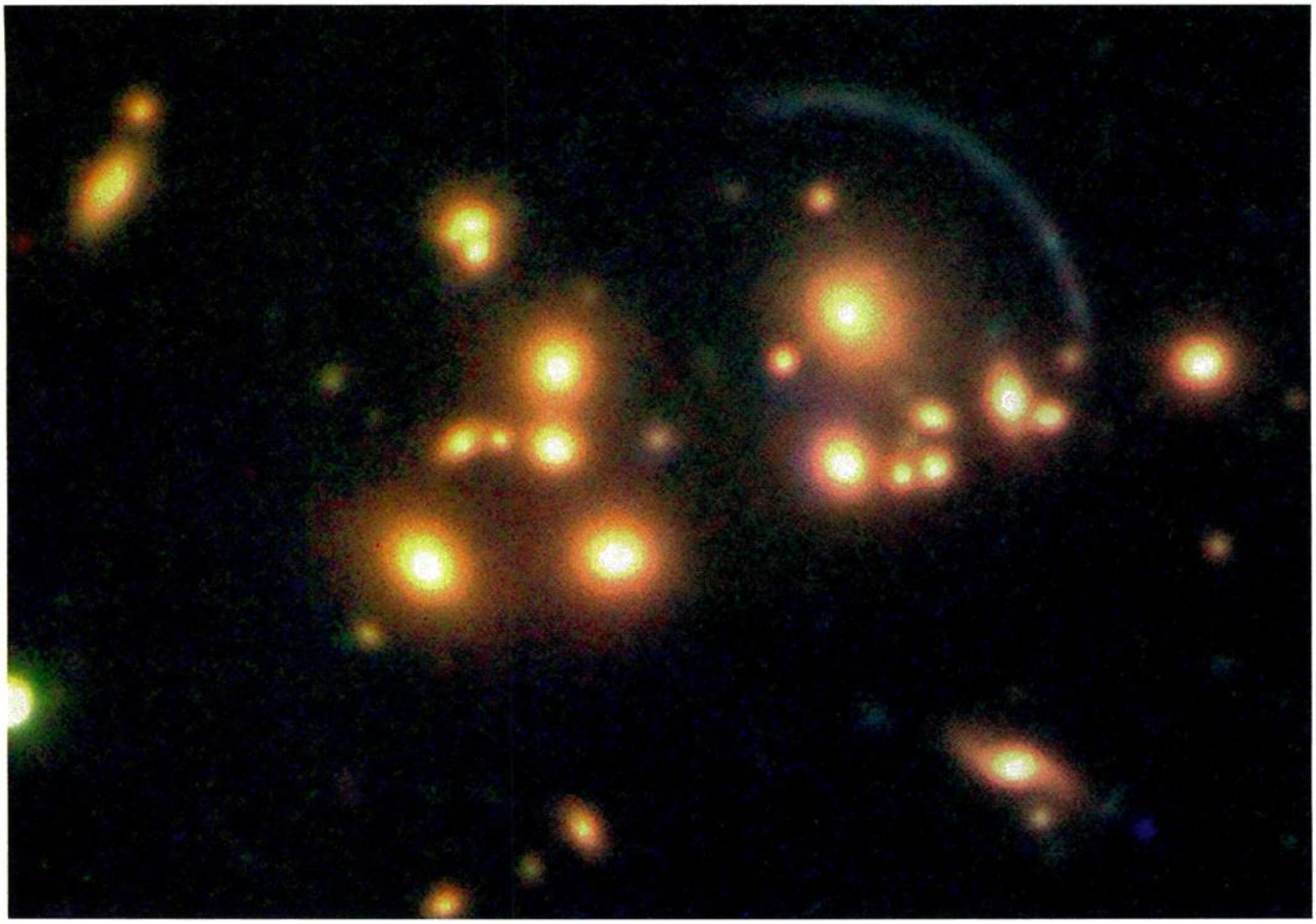
And so his preference is for what he calls a "one-shot" universe with "one beginning and one Big Bang." A universe exactly like the one produced by the pea instanton.

NOT EVERYONE'S CUP OF TEA

But some cosmologists say there are fatal flaws in Turok and Hawking's beloved instanton. To begin with, critics say the Cambridge scientists have not eliminated the singularity entirely: It survives as a single point inside the primordial instanton.

There are other criticisms as well. Linde points out that the pea instanton gives rise to a universe that is *too* open. The density of matter is so low, in fact, that galaxies would be few and far between; even using the Hubble Space Telescope we wouldn't be able to see another galaxy from our own.

Moreover, in explaining how the universe could have come from nothing, the pea instanton uses the idea of "quantum tunneling," Linde says. In the mathematical language of quantum physics, tunneling describes how a



The arc is a distant galaxy distorted by the gravity of a nearer cluster, allowing astronomers another way to gauge a cluster's mass.

Image of galaxy cluster CL 2244-02 by ESO

particle or a field can move from one side of a seemingly insurmountable barrier to the other without actually passing over or through the barrier in a classical sense. The way Linde sees it, Turok and Hawking's instanton describes the origin of the universe as a quantum tunneling event from a state of nothingness to a state of existence.

"This is like creating a hydrogen atom from nothing. I cannot justify it. I cannot understand it," Linde laments.

Turok replies that Linde misunderstands what he and Hawking have done. "It's *not* tunneling," Turok insists. The pea instanton is not, in fact, created from nothing. "Nothing" simply has no meaning in this context. The instanton, meaning the universe at its birth, just *is*. In essence, the theory shows how the laws of physics make its existence inevitable.

"It really is a rather unique thing and I don't think this is widely understood," Turok says.

As to the pea instanton universe being too open, Turok agrees. But he remains undaunted. "The fact that it's wrong by a factor of 30 is encouraging because the calculation was done with a very simple model and yet it's not *that* far wrong." So for Turok, the fact that the pea instanton universe is too open is simply cause for further tinkering.

Finally, the surviving singularity within the instanton is, in his words, "so mild that, like the singularity in the electric field in the center of a hydrogen atom, one can still calculate the quantum properties of the universe without any ambiguities."

He points out that "there are singularities within black holes, yet we don't doubt that black holes exist." So just because there is a singularity within the instanton doesn't mean that the model should be tossed out. "The presence of a singularity simply says you don't know what you're doing there," Turok says. "It's still possible that the physics away from the singularity is fine."

"I like to say that what we've done is sidestep the singularity rather than avoid it altogether," Turok concludes. "We've found a way to go back to the beginning of time and go *around* the singularity."

Time will tell whether he and Hawking have succeeded. Two new satellites, NASA's Microwave Anisotropy Project mission and the European Space Agency's Planck Surveyor, scheduled for launch early in the next century, should be able to test their theory by looking for evidence of the quantum fluctuations — the dimples — predicted by the pea instanton theory.

Of course, even if Turok and Hawking are onto something with their pea instanton, it would still leave a very fundamental question unanswered: How did the pea get there?

Turok and Hawking say it's meaningless to ask the question. There is no "outside" of the pea, no "before" the pea. It just is, an object implied by the very laws of physics.

But what created those laws?

Says Turok: "We don't know how to create physics from nothing."

Tom Yulsman, former editor of Earth magazine and a contributing editor to Astronomy, is a journalism professor at the University of Colorado at Boulder.

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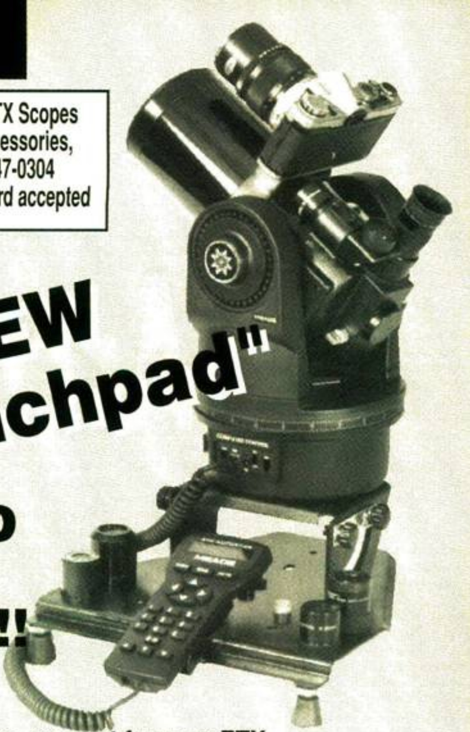

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Architects of Time

With a horseshoe of rocks, a preliterate culture marked time in the sky.

by James Trefil

Most of us have a pretty good intuitive grasp of the way time affects our lives. Yet when it comes to defining the essence of time, most of us agree with St. Augustine, who wrote: "What is time? If no one asks me, I know what it is. If I wish to explain what it is to him who asks, I do not know."

We have a sense that time is measured in terms of repeating processes in nature — the swing of a pendulum, the turning of Earth, the stately progression of the seasons. When it comes to measuring time, human beings have traditionally tried to find a steadily repeating process to serve as a fundamental definition — the "tick" of the clock.

The first processes that people used as timekeepers were astronomical. In fact three separate astronomical processes make perfectly good "clocks." One is the rotation of Earth around its own axis, which gives us the unit of time we call the day. Another is the time that it takes Earth to move in its orbit around the sun, which defines the year. Finally, although we no longer use it very much, there is a third clock in the sky that moves through 29.5 days — a synodic month — the period it takes for the moon to run though all its phases.

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No one knows exactly when the first human being figured out that you could tell time by watching the heavens. Some archaeologists have contended that marks on 20,000-year-old bones taken from Africa and Europe are humanity's first attempt to keep track of the lunar month. A skeptic (and there are many) looking at the same bones might simply see something that had been used as a knife sharpener. Whether or not Ice Age people kept formal astronomical calendars is very much an open issue. We do know that people in societies without writing or iron tools were capable of doing so.

On the plains of Wiltshire, south of London, there is a remarkable monument to the ability of human beings to keep track of time by using the stars. It is called Stonehenge, which means "hanging stones." I can remember going there when I was a student at Oxford in the 1960s and walking around them as I wished, in the days when it was simply a bunch of stones sitting out on the plain. It's too bad that today, in order to protect the monument, the British government has had to fence the stones and keep visitors at a distance.

The oldest part of Stonehenge, called Stonehenge I, consists of little more than a circular ditch dug in the chalky soil of the Salisbury plain, with the soil taken from the ditch piled up to make an embankment about 6 feet tall. This part of the monument is some 320 feet across. Inside this large circle are the things that we normally think of as Stonehenge proper — circles of stones that once stood upright, and most photogenic of all, the large horseshoe arrangements of standing stones at the center. These last, the so-called trilithons, consist of upright stones supporting horizontal lintels, and the largest of them weighs in around 45 tons.

Legends about the origin and purpose of Stonehenge are legion. It has, for example, been attributed to Druids, and modern-day Druids in England call it theirs. We know, however, that it was built long before the Celtic invasion of Great Britain, so although the Druids might have used it, they certainly did not build it. There are other legends ascribing it to Julius Caesar, Merlin the Magician (who flew the stones in from Ireland), and extraterrestrials in flying saucers. Actually, you do not have to go to these lengths to explain Stonehenge. British students have shown that stones such as those in the monument can easily be moved around by a team of strong young men — one method featured on a BBC television program involved tying a stone to a sleigh and then pulling the sleigh over log rollers.

Several questions that come quickly to mind about a monument such as Stonehenge: Who built it? When was it built? How was it built? Why was it built?

You must answer the "when" question before you can make much progress on the others. Carbon dating comes to the rescue. The idea behind this is simple. The upper atmosphere of Earth is constantly being bombarded by high-energy particles — called cosmic rays — and when they hit the atmosphere they break up the nuclei they encounter, creating neutrons in the process. Some of these neutrons strike the nuclei of ordinary nitrogen atoms, creating an atom with a nucleus that has 6 protons and 8 neutrons. This atom is chemically identical to ordinary carbon (which has 6 protons and 6 neutrons) but weighs a little more. It is called carbon-14 to distinguish it from its more common sibling, carbon-2. Carbon-14 is radioactive, and in 5,860 years half the carbon-14 nuclei in any collection will have undergone radioactive decay back to nitrogen-14.

While it's around, carbon-14 is taken into the bodies of living things just like carbon-12. Thus, when any living thing dies, it holds a certain amount of carbon-14. The subsequent decay of the nuclei gives us a kind of clock that tells us when that particular thing died and stopped taking in carbon. If we found a piece of leather with half of the carbon-14 with which it started, we would know that the leather was made from an animal that died about 5,860 years ago. In the 1950s, Harold Urey of the University of Chicago developed the carbon-dating technique, and it was immediately put to use by paleontologists and archaeologists everywhere around the world.

Now you may be wondering what this carbon-14 has to do with dating something such as Stonehenge, since the materials of Stonehenge (rock) do not take in carbon and were never alive. The answer is somewhat surprising. Think about the oldest part of Stonehenge — the ditch and embankment that encircles the entire monument. In order to dig this ditch, Neolithic people would take a deer antler and pound it into the hard chalk, loosen it, and pull out chunks. The antlers would occasionally break, however, leaving points embedded in the chalk. In addition, the worker would often just throw away the now useless antler, which would remain in the embankment until scientists dug it up. Applying the carbon-dating technique would tell us when the deer had lost its antlers, providing an estimate of when human beings worked on the ditch. Other kinds of materials — charcoal from a fire, scraps of wood — can be used in the same way to date the various parts of the structure.

Using this technique, scholars now date the bank-and-ditch structure to around 3000 B.C., the first stones to about 2600 B.C., the large standing stones to about 2100 B.C., and the last adjustments to the structure to about 1800 B.C. Thus, the construction of Stonehenge took 1,200 years — much longer than Europeans have inhabited North America. It was built by successive waves of immigrants to southern England. Most of them did not have metal tools or a written language. Anthropologists are also in agreement that quarrying, transporting, and erecting the stones would be well within the technical capabilities of the people who lived around Stonehenge while it was being built. There is, in other words, no need to invoke either Merlin the Magician or extraterrestrials in flying saucers!

With the when, who, and how disposed of, we can turn to the more interesting question of why in the world anyone would go through all the trouble of setting those huge stones upright on the plains of Salisbury. It is almost certain that the only thing that could inspire this much effort over that period of time would be a religion or religious practices, and most scholars accept that

Stonehenge was first and foremost the site of religious and/or civic celebrations. But is that all there is?

In 1963, British astronomer Gerald Hawkin published an article in *Nature*, followed by a book, *Stonehenge Decoded*. He proposed a rather startling hypothesis for at least one purpose of this ancient monument. Having grown up in the neighborhood of Stonehenge, Hawkin began his analysis by recalling that when he stood in the center of the stones as a boy, he felt as if the builders, by the placement of the stones, had wanted to force him to look in certain directions. Using the best computer available at the time, Hawkin fed these lines of sight into a program designed to see whether they matched the lines of sight to any significant astronomical events.

> There is nothing that annoys a scientist more than having an old problem in his or her field solved by someone from outside.

Fully 24 of the lines pointed to significant astronomical events. The most famous of these are the alignments that point to the spot on the horizon at which the sun rises on the summer and winter solstices, but there were many lines pointing to the rising and setting of the full moon nearest those dates as well. Hawkin discovered Stonehenge was not only a religious site, it also was an astronomical observatory and calendar. Stonehenge was a device by which the builders could tell, on an annual basis, when Earth arrived at a certain point in its orbit around the sun.

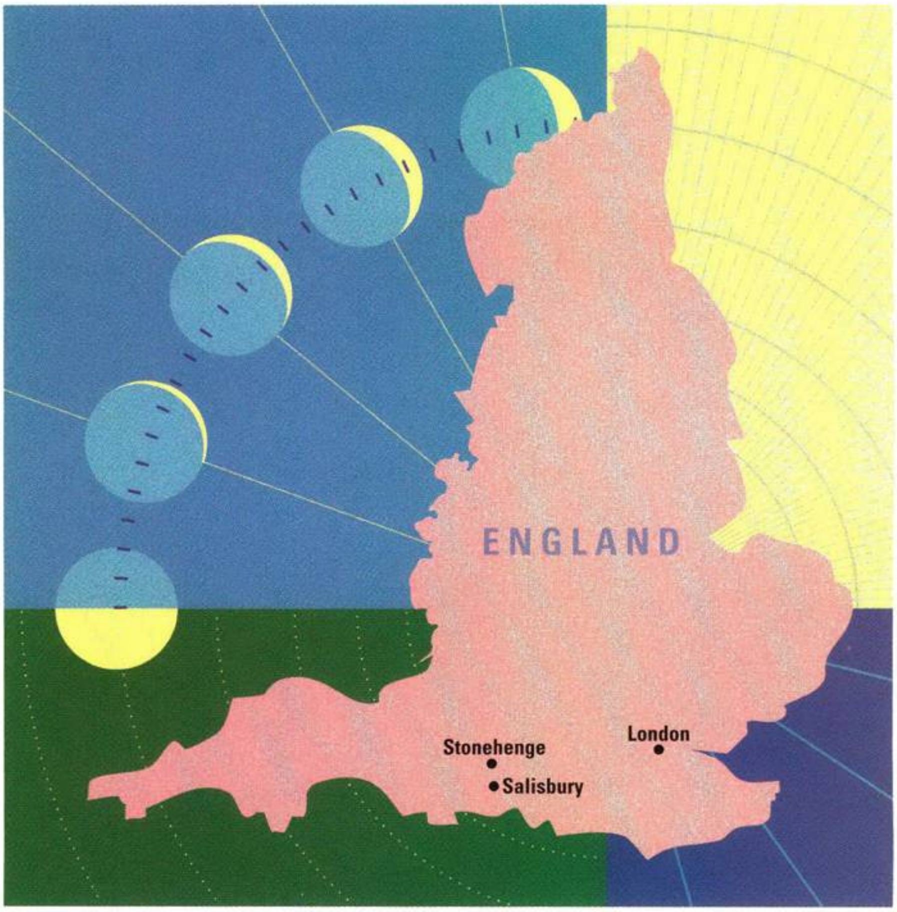
This observation about the astronomical nature of Stonehenge was greeted with great excitement by the astronomical community — it was instrumental in spawning a new field, called archaeoastronomy, devoted to the study of the astronomical function of ancient monuments. Over the years, astronomers have found similar purposes for many other ancient monuments in the old and new world.

Hawkin's discovery also caused what my daughters would call a "hissy fit" among archaeologists. There is nothing that annoys a scientist more than having an old problem in his or her field solved by someone from outside. (If you doubt this comment, just think about the reaction of paleontologists to the discovery by Luis and Walter Alvarez that the extinction of the dinosaurs was caused by the impact of a large meteor on the surface of the planet.) This reaction usually manifested itself in peevish comments by archaeologists to the effect that Stonehenge was more than just an astronomical observatory, but had some social function as well.

The construction of Stonehenge symbolizes humanity's attempt to cope with the passage of time thorough the use of astronomy. Perhaps more importantly, Stonehenge illustrates one of the most important things about the universe in which we live — that it is regular and predictable. It would scarcely be worthwhile for people to haul huge stones over miles of rough terrain to provide a ceremonial observation of the summer solstice if that solstice appeared in a different part of the sky every year. By its sheer bulk, Stonehenge reminds us that the basic premise of science (that we can understand and predict the universe that we live in) is a valid one.

Realizing that the movement of the sun and stars can be used to measure time is just the beginning. To construct a useful calendar using this insight, you have to allow for one inescapable fact: There are an uneven number of days in a year. The year is actually 365 days, 5 hours, 48 minutes, and 46 seconds (or 365.2422 days) long. The turning of Earth and its motion around the sun are not related to each other.

To see why this makes everything so difficult, imagine you were a priest-



Astronomy: Terri Field

astronomer at Stonehenge and, on the day the sun came up to mark midsummer, you began carving notches in a stick. On the morning you carved the 365th notch, Earth would not be in exactly the same place in its orbit as it had been when you carved the first. It would not be in that place until roughly 6 hours after sunrise. Each year Earth would slip another six hours — about one full day every four years.

The central problem of calendar-making is to devise a system where the year has an integer number of days, but which does not slip. If our calendars failed to do this, after some time we would have bright summer sunshine in January. More relevant to the original calendar makers, the major religious festivals, linked as they are to agricultural events such as planting and harvest, would start to get seriously out of sync with the seasons.

There were many historic attempts at constructing calendars that took into account the different lengths of the day and year (and sometimes the lunar month as well). The Egyptians had a 360-day year followed by a five-day party (an altogether splendid idea, it seems to me). Others tried to construct calendars based on the movements of the moon, in which the number of months varied each year.

The calendar reform that leads most directly to our current system was undertaken during Julius Caesar' reign in Rome, in 46 B.C. By this time, the calendar was about three months out of line with the seasons. Sosigenes, who was a chief calendar advisor, had to first bring religious holidays back into line with the seasons and then make sure this problem did not arise again.

An extra month was added to the year in 46 B.C., which was known as the "year of confusion" and wound up lasting 445 days. Then it was decreed that every year would be 365 days long and the slip in Earth's orbit would be taken into account by adding one day every four years — our current leap year. In this way, Earth slips back approximately a quarter day each year and then on leap year, an extra day is added to make up. This Julian calendar was a vast improvement over what came before it, and it misses the true length of a year by only 11 minutes and 14 seconds.

Nevertheless, even a short time such as this will accumulate over the millennia. By 1582, the 11-minute slip had grown to about 11 days, and Pope Gregory XIII convened a commission to solve the problem. Vatican astronomers may have motivated the Pope by taking him into a room known as the "Tower of the Winds," which had a narrow window on the south wall and a kind of sundial built into the floor to mark the seasons' progression. On March 21, the bright spot created by the sun was a couple feet away from the place where it was supposed to be — dramatic proof that something had to be done.

After a lot of haggling, much of it because Easter must follow Passover whose date is set by the old Jewish lunar calendar, the modern Gregorian calendar was promulgated. For 1582, the day after October 4 was declared to be October 15, making it the shortest year in history. Although some countries refused to accept the new calendar (it wasn't until 1752 that Great Britain did so, and Russia stayed on the old calendar until 1917), it caught on quickly and is now used almost universally.

In the Gregorian calendar, the leap year rule was changed so that those years that fall on the century but are not divisible by four hundred are not considered leap years. What this means is

Though claimed by modern-day Druids in England as theirs, Stonehenge was built long before the Celts invaded Great Britain.

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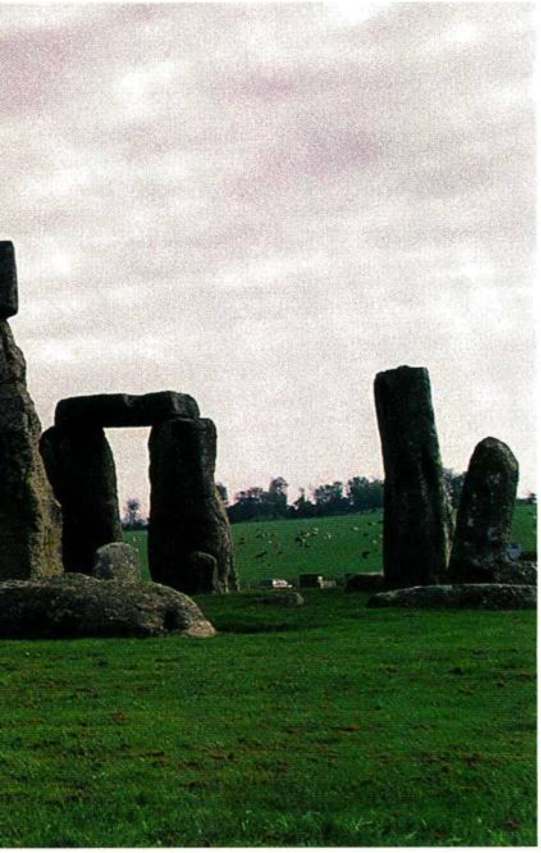
that 1600 was a leap year and 2000 will be, but 1700, 1800, and 1900 were not. This had the effect of making the average day length in the calendar year 365.2425 days — which is only .0003 days (about 4 minutes) different from the actual day. This was a pretty good correction — using the Gregorian scheme, it would take about 3,300 years for Earth to slip one day.

But all this fiddling with calendars doesn't ask the most interesting question of all — how steady is the "ticking" marked by Earth's rotation? Is each 24-hour day really as long as every other?

The rotation of Earth is subject to the ordinary laws of physics and can be changed by outside forces. We know, for example, that the tides raised by the moon drain energy away from the rotation of Earth. This has the effect of slowing down rotation and making the day longer. Investigations on fossil corals show that 200 million years ago a day was only 22 hours long. Today, tides slow the rotation down by about 1.6 milliseconds per day. Because of the tides, the 21st century will be almost a minute longer than the 20th.

Changes in the length of day at the millisecond level couldn't have been measured by Julius Caesar or Pope Gregory, of course, but by the end of the 19th century, pendulum clocks began to achieve this kind of accuracy. In other words, by the beginning of the 20th century, human beings could build clocks that kept time more accurately than Earth itself.



One way of thinking about the accuracy of a clock is to ask the number of decimal places to which it can be trusted. A clock that lost one second a year, for example, would be accurate to seven decimal places (there are about 30,000,000 seconds in a year) and would be expected to err in the seventh place. A good quartz wristwatch should keep time this accurately. If we say that the rotation of Earth causes the length of the day to vary by several milliseconds per day, then Earth is a clock accurate to about eight decimal places. (There are 86,400 seconds — 86,400,000 milliseconds — in a day.) Compare the length of the day to any clock more accurate than this and you will see that no two days are exactly the same length.

Because of the tides, the 21st century will be almost a minute longer than the 20th.

As clocks got more accurate, the vagaries of Earth's rotation became more obvious. At the same time, the need for industrial time standards grew, and eventually the turning of the Earth, as bumpy and uneven as it turned out to be, was abandoned. Today, we use atomic clocks to keep time. In these clocks, a carefully prepared beam of cesium atoms is fed into a microwave and the frequency of the microwaves is adjusted to the precise value needed to cause a certain rearrangement of the electrons in the atom. Like the electric current in the wires in your house (which reverses itself 60 times each second), the radiation in a microwave cavity changes direction repeatedly. In fact, the microwaves in a tuned atomic clock will reverse themselves 9,192,631,770 each second when they are causing the rearrangement of electrons. In 1967, the International Committee of Weights and Measures adopted this number as the definition of a second, so that a second is now defined as the time it takes radiation in a microwave cavity to reverse itself more than 9 billion times.

Atomic clocks used by the National Institutes of Standards and Technology in the United States are accurate to better than 13 decimal places. The use of the atomic clock has an advantage: No snow falls on the electron, so every cesium atom in the universe tells the same time. Such clocks are easy to build and operate, so that even relatively small laboratories can have their own. And they are extremely accurate.

In fact, atomic clocks run by standards agencies around the world work together to keep track of Earth's rotation. In effect, the various clocks "vote" on when Earth has slowed down a half second, and scientists then insert a "leap second" into Universal Time to compensate. Look for the small items in your newspaper that accompany this event — they occur every few years.

But scientists, driven by an industrial need for frequency standards, keep looking for better timekeepers. One intriguing notion (now being actively pursued) is to look at radiation from pulsars. Pulsars are rapidly rotating neutron stars, the remains of supernovae, that beam regular pulses of radio waves toward Earth. Because pulsars rotate quickly, and because we can average their signals over long periods of time to get increased accuracy, some scientists have suggested that their rotation could be used as the "tick" of an even better clock. I have heard claims that accuracies up to 15 decimal places might be possible using pulsars.

So who knows? Maybe someday modern scientists, like those ancient priest-astronomers at Stonehenge, will again look to the skies to tell us where we are in the march of time.

James Trefil is a member of Astronomy's *Editorial Advisory Board. His most recent book,* Other Worlds, *was published in June 1999 by National Geographic Society Books.*

The Art of
SKYSPEAK

Is it Betelgeuse or Beetlejuice? Pronouncing astronomical names requires learning a simple set of rules.

by Bob Berman

Moviegoers seemed to enjoy *Contact*, but each time an actor mentioned Vega, I cringed. That famous summer star, the fictional site of the aliens' transmitter, was consistently pronounced VAY-gah. The renowned astronomer Carl Sagan had been involved in the film before his untimely death, and surely he knew that the star is preferably expressed as VEE-gah — a name that comes from an odd Arabic term meaning "a falling vulture." But the producers apparently felt that few would know or care, and VAY-gah sounded more exotic.

Such phonetic star butchery may seem inconsequential to all but the handful of eccentrics who want to verbalize celestial names correctly. But even those who are indifferent about pronunciation have to admit that we astronomers, whether backyard or professional, have a bit of a problem. Celestial objects have such strange, alien names that it's easy to botch the pronunciation of many of them. While mispronunciation of astronomical names can interfere with communication and misinform the public, it's mostly a source of embarrassment. When you mention SPICK-ah and someone in your astronomy club pedantically points out that it's actually pronounced SPY-kah, you feel your face getting as flushed as Antares (an-TARE-eez) and wish you could crawl into a black hole.

Vē-ga/'ve-ge, 'va-/n [NL, fr. Ar *(al-Nasr) al-Waqi*', lit., the falling (vulture)] : a star of the first magnitude that is the brightest in the constellation Lyra

PRONOUNCING THE CONSTELLATIONS

NAME	PRONUNCIATION	GENITIVE	PRONUNCIATION
Andromeda	an-DROM-eh-dah	Andromedae	an-DROM-eh-day
Antlia	ANT-lee-ah	Antliae	ANT-lee-ay
Apus	AY-puss	Apodis	APE-oh-diss
Aquarius	ah-KWARE-ee-us	Aquarii	ah-KWARE-ee-eye
Aquila	AK-weh-lah uh-KWILL-uh	Aquilae	AK-weh-lay uh-KWILL-ay
Ara	AY-rah	Arae	AY-ray
Aries	AIR-ee-eez	Arietis	ah-RYE-eh-tiss
Auriga	oh-RYE-gah	Aurigae	oh-RYE-gay
Boötes	boh-OH-teez	Boötis	boh-OH-tiss
Caelum	SEE-lum	Caeli	SEE-lie
Camelopardalis	kah-MEL-oh-PAR-dal-iss	Camelopardalis	kah-MEL-oh-PAR-dal-iss
Cancer	KAN-sir	Cancri	KANG-kry
Canes Venatici	KAY-neez veh-NAT-ih-sigh	Canum Venaticorum	KAY-num veh-NAT-ih-KOH-rum
Canis Major	KAY-niss MAY-jer	Canis Majoris	KAY-niss mah-JOR-iss
Canis Minor	KAY-niss MY-ner	Canis Minoris	KAY-niss my-NOR-iss
Capricornus	KAP-rih-KOR-nus	Capricorni	KAP-rih-KOR-nye
Carina	kah-RYE-nah	Carinae	kah-RYE-nay
Cassiopeia	KASS-ee-oh-PEE-uh	Cassiopeiae	KASS-ee-oh-PEE-yay
Centaurus	sen-TAUR-us	Centauri	sen-TAUR-eye
Cepheus	SEE-fee-us	Cephei	SEE-fee-eye
Cetus	SEE-tes	Ceti	SEE-tie
Chamaeleon	kah-MEE-lee-un	Chamaeleontis	kah-MEE-lee-ON-tiss

So how do you articulate what you're observing? When you contentedly look at Orion's famous foot star Rigel through your scope and a friend asks what you're viewing, how do you know what to say? REE-j'l? RYE-j'l? REE-g'l? The brilliant blue supergiant is not exactly a household name, nor is it anything you've ever heard on TV or in conversation.

BETELGEUSE OR BEETLEJUICE?

Now, some people will didactically offer unsolicited corrections if you mispronounce words such as template and restaurateur (the right way is TEM-plit and res-tau-ra-TEUR with no "n"). Astronomy, however, is a specialized pursuit: Virtually nobody out there notices our improper usage, and there's almost no chance for improvement unless we make the effort ourselves.

And the errors are widespread. Not simply confined to star names, one hears moons, asteroids, comets, and constellations routinely mispronounced. With lesser-known objects such as the constellation Vulpecula (vul-PECK-yoo-lah), or the star Zubeneschemali (zoo-BEN-ess-sheh-MAY-lee), or Saturn's moon Dione (die-OH-nee), the rarity of the occasions when we might need to enunciate them makes their correct expression less important. But anyone seriously interested in the sky, especially those involved with lecturing or public education, should probably try to correctly pronounce all 21 first-magnitude stars and major constellations.

Not that anyone can be blamed. Virtually the whole world now says Beetlejuice, since the 1988 movie with Michael Keaton, Alec Baldwin, and Geena Davis was spelled and spoken that way. Indeed, no more than 1 astronomer in 10 bestows that famous red star of Orion with its preferred title of BET'l-jooz.

I say "preferred" because a certain amount of latitude is permitted with some stars and constellations. Before you send letters to this magazine, remember that there is disagreement even among authorities on the pronunciation of some stars and constellations. But if you say things according to the tables in this article, you can be confident that some, if not all, authorities and references will support you.

For this article, I've used the research of the late George A. Davis, a well-known Arabic scholar and amateur astronomer of Buffalo, New York, who was widely recognized as an expert on ancient constellations and their mythology. I have also consulted *The Columbia Encyclopedia* and the *New World Dictionary*, second college edition. If there's disagreement, it will be noted.

For example, Davis insists that it *has* to be BET'l-jooz. The dictionary says that BET'l-jooz is indeed preferred but that two other pronunciations are acceptable (BAIT'l-jooz and BEET'l-jooz), while *The Columbia Encyclopedia* (but not others) prefers BEET'l-jooz. However, in most cases no such controversy exists. While the narrator in the famous short movie *Powers of Ten* says ARK-ter-us, all authorities agree that it should be spoken as ark-TOOR-us.

Things are just as bad when constellations are mentioned. A lecturer's low voice and hesitant tone reveals his or her insecurity when speaking about such common northern star patterns as Auriga, Boötes, or Camelopardalis. And when the

PRONOUNCING THE CONSTELLATIONS (cont.)

NAME	PRONUNCIATION	GENITIVE	PRONUNCIATION
Circinus	SUR-sih-nuss	Circini	SUR-sin-eye
Columba	koh-LUM-bah	Columbae	koh-LUM-bay
Coma Berenices	KOH-mah BARE-ah-NYE-seez	Comae Berenices	KOH-may BARE-ah-NYE-seez
Corona Australis	koh-ROH-nah oss-TRAY-liss	Coronae Australis	koh-ROH-nay oss-TRAY-liss
Corona Borealis	koh-ROH-nah BOH-ree-AL-liss koh-ROH-nah BOH-ree-AY-liss	Coronae Borealis	koh-ROH-nay BOH-ree-AL-liss koh-ROH-nay BOH-ree-AY-liss
Corvus	KOR-vuss	Corvi	KOR-vie
Crater	KRAY-ter	Crateris	kray-TEE-riss
Crux	KRUX	Crucis	KROO-sis
Cygnus	SIG-nuss	Cygni	SIG-nye
Delphinus	del-FIE-nes	Delphini	del-FIE-nye
Dorado	doh-RAH-doh	Doradus	doh-RAH-doos
Draco	DRAY-koh	Draconis	dreh-KOH-niss
Equuleus	eh-KWOO-lee-us	Equulei	eh-KWOO-lee-eye
Eridanus	ih-RID'n-us	Eridani	ih-RID'n-eye
Fornax	FOR-naks	Fornacis	for-NAY-siss
Gemini	JEM'n-eye	Geminorum	JEM-eh-NOR-um
Grus	GRUSS	Gruis	GROO-iss
Hercules	HUR-kyuh-leez	Herculis	HUR-kyuh-liss
Horologium	HOR-uh-LOW-jee-em	Horologii	HOR-oh-LOW-jee-eye
Hydra	HY-drah	Hydrae	HY-dray
Hydrus	HY-druss	Hydri	HY-dry
Indus	INN-duss	Indi	INN-die

time arrives for the lecturer to say Coma Berenices or Canes Venatici — Fageddaboudit.

Even more amazing is when something as commonplace as a planet manages to be mispronounced. Many amateur astronomers, perhaps insecure about sounding "different," say your-AIN-us, the way most of the public does, instead of the correct YER'n-us. While language does evolve to allow widespread mispronunciations to gain eventual acceptance (in some dictionaries TRAN-see-ent is now listed as an acceptable second choice for transient, after the standard TRAN-shent), Uranus can never evolve because it is named for a Greek god.

The problem is hardest for beginners, particularly those with no background in mythology. What unsuspecting novice would guess that Pluto's moon Charon is pronounced like Karen? How many realize that the largest minor planet in the solar system, Ceres, could best be pronounced by visualizing it as winning the asteroidal world "series?"

There really isn't any dispute or ambiguity in most such cases. Like the time of day, there is only one "right" way to utter these names. You may as well be the one in your club to carry the banner of astral fluency; let the others learn from you. Where there's more than one acceptable choice, as in Jupiter's moon Io (you can say either EE-oh or EYE-oh) or the constellation Aquila (AK-weh-lah or uh-KWILL-uh), you don't want to obnoxiously suggest the "better" way; that's not the technique for making friends. Let people say Beetlejuice to their heart's content. But when you hear Spica being pronounced SPEE-kah, a gentle correction may be in order, if only to help preserve a linguistic, cultural, and astronomical heritage that has spanned centuries and civilizations.

STARS

Of the brightest stars, only two or three dozen still have proper, traditional names in common use. Once we get down to third magnitude or fainter, it's usually best to use the Bayer designation of a Greek letter followed by the constellation's Latin genitive form. But often the choice is yours: Gemini's third brightest star can either be called Alhena (al-HEN-ah) or Gamma Geminorum (GAM-ah JEM-eh-NOR-um).

Probably the most valuable tip is to know that when star names were first translated into English from their original Arabic, Greek, or Latin, they were spelled phonetically — just the way they're pronounced. Therefore, you're almost always correct when you say it just the way it looks, with an "i" pronounced like the letter "i" instead of Latinized by saying "ee." So when you see Mira, your first guess would probably be MY-ruh (which would be right), instead of getting fancy-schmancy and tossing it out as MEE-ruh. Similarly, Gemini is pronounced JEM'n-eye, not JEM'n-ee.

With that in mind, try your hand with Orion's stars: Alnitak, Alnilam, Bellatrix. If you said al-NIGH-tak and al-NIGH-lam, then, by George, you've got it. As for the Hunter's right shoulder star, there's a strong tendency to want to say BEL-la-trix, since Bella means "beautiful" in Italian. But it's beh-LAY-trix.

Obviously, then, the say-it-as-it's-spelled rule doesn't help you figure out which syllable gets the emphasis, and in some

PRONOUNCING THE CONSTELLATIONS (cont.)

NAME	PRONUNCIATION	GENITIVE	PRONUNCIATION
Lacerta	lah-SUR-tah	Lacertae	lah-SUR-tay
Leo	LEE-oh	Leonis	lee-OH-niss
Leo Minor	LEE-oh MY-ner	Leonis Minoris	lee-OH-niss my-NOR-iss
Lepus	LEE-pus	Leporis	LEE-por-iss
Libra	LIE-brah	Librae	LIE-bray
Lupus	LOO-puss	Lupi	LOO-pie
Lynx	LINKS	Lyncis	LYNN-sis
Lyra	LIE-rah	Lyrae	LIE-ray
Mensa	MEN-sah	Mensae	MEN-say
Microscopium	MY-kroh-SKOH-pee-em	Microscopii	MY-kroh-SKOH-pee-eye
Monoceros	moh-NOSS-er-us	Monocerotis	moh-NOSS-er-OH-tiss
Musca	MUSS-kah	Muscae	MUSS-say
Norma	NOR-mah	Normae	NOR-may
Octans	OCK-tanz	Octantis	ock-TAN-tiss
Ophiuchus	OFF-ee-YOO-kuss	Ophiuchi	OFF-ee-YOO-kye
Orion	oh-RYE-un	Orionis	OH-rye-OH-niss
Pavo	PAY-voh	Pavonis	pah-VOH-niss
Pegasus	PEG-ah-suss	Pegasi	PEG-ah-sigh
Perseus	PURR-syoos or PURR-see-us	Persei	PURR-see-eye
Phoenix	FEE-nix	Phoenicis	fee-NYE-sis
Pictor	PICK-ter	Pictoris	pick-TOR-iss
Pisces	PIE-seez	Piscium	PIE-see-em

cases the right way to say it sounds awkward or counterintuitive. Who would guess that the brightest star of the Pleiades cluster, Alcyone, is pronounced al-SIGH-oh-nee, or that Procyon is not pro-SIGH-on, the way so many incorrectly say it, but rather PRO-see-on? I vividly remember those two examples because it was hard for me to reprogram myself at age 14 or so to break the incorrect habit I'd had during my first five years of skygazing. But if I could do it, so can anyone; it was easier than breaking other habits, such as nail biting.

Another universal hint is that "ch" is almost always pronounced as if it were a "k." Hence, Kochab, Chara, and Almach are KOH-kab, KAH-ruh, and AL-mahk.

Yet another hint is that many stars begin with "Al" simply because this means "the" in Arabic, and most star names are of Arabic origin; they originally meant the this or the that. So when you run into names such as Aldebaran ("the follower" because it follows the Pleiades across the sky), you can always pronounce the "al" the same way as the common English first name. Try it now, with Alkaid, Albireo, Alphecca, Altair, Alrescha, Alnilam, Algeiba, Alhena, Alcor, Alioth, Alphard, Almach, or Algol. It becomes the stressed syllable a little less than half the time (as in the last five of our examples, above).

CONSTELLATIONS

Not many people are going to blow the most common star groups by saying things like "OAR-ee-on, the Hunter" but you'll sometimes hear kass-ee-OH-pee-uh instead of the correct KASS-ee-oh-PEE-uh. Also commonly overheard are the erroneous Scorpio instead of Scorpius or LEER-ah instead of the correct LIE-rah. The gremlins I hear mispronounced the most are Auriga (say: oh-RYE-gah), Boötes (boh-OH-teez), Draco (DRAY-koh), and Eridanus (ih-RID'n-us).

PRONOUNCING THE 21 BRIGHTEST STARS IN THE NIGHT SKY

1. Sirius	SEAR-ee-us	8. Procyon	PRO-see-on	15. Antares	an-TARE-eez
2. Canopus	kah-NO-puss	9. Achernar	AY-ker-nar	16. Spica	SPY-kah
3. Alpha Centauri	AL-fah sen-TAUR-eye	10. Betelgeuse	BET'l-jooz	17. Pollux	PAUL-ux
4. Arcturus	ark-TOOR-us	11. Beta Centauri	BAY-tah cen-TAUR-eye	18. Fomalhaut	foo-mal-HOUT
5. Vega	VEE-gah	12. Altair	al-TAH-yir or al-TARE	19. Deneb	DEN-ebb
6. Capella	kah-PELL-ah	13. Aldebaran	al-deb-ah-RAN	20. Beta Crucis	BAY-tah KROO-sis
7. Rigel	RYE-j'l	14. Acrux	AY-krux	21. Regulus	REG-yoo-luss

PRONOUNCING THE CONSTELLATIONS (cont.)

NAME	PRONUNCIATION	GENITIVE	PRONUNCIATION
Piscis Austrinus	PIE-siss oss-TRI-nuss	Piscis Austrini	PIE-siss oss-TRI-nye
Puppis	PUP-iss	Puppis	PUP-iss
Pyxis	PICK-sis	Pyxidis	PICK-seh-dis
Reticulum	reh-TICK-yah-lum	Reticuli	reh-TICK-yah-lie
Sagitta	sa-JIT-tah	Sagittae	sa-JIT-tay
Sagittarius	SAJ-eh-TARE-ee-us	Sagittarii	SAJ-eh-TARE-ee-eye
Scorpius	SKOR-pee-us	Scorpii	SKOR-pee-eye
Sculptor	SKULP-ter	Sculptoris	skulp-TOH-riss
Scutum	SKOO-tem or SKYOO-tem	Scuti	SKOO-tie or SKYOO-tie
Serpens	SUR-penz	Serpentis	sur-PEN-tiss
Sextans	SEX-tanz	Sextantis	sex-TAN-tiss
Taurus	TOR-ess	Tauri	TOR-eye
Telescopium	TEL-ah-SKOH-pee-um	Telescopii	TEL-ah-SKOH-pee-eye
Triangulum	tri-ANG-gyah-lum	Trianguli	tri-ANG-gyah-lie
Triangulum Australe	tri-ANG-gyah-lum OSS-tray-lee	Trianguli Australis	tri-ANG-gyah-lie oss-TRAY-liss
Tucana	too-KAY-nah	Tucanae	too-KAY-nay
Ursa Major	UR-sah MAY-jer	Ursae Majoris	UR-say mah-JOR-iss
Ursa Minor	UR-sah MY-ner	Ursae Minoris	UR-say my-NOR-iss
Vela	VEE-lah	Velorum	vee-LOH-rum
Virgo	VUR-go	Virginis	VUR-jinn-iss
Volans	VOH-lanz	Volantis	voh-LAN-tiss
Vulpecula	vul-PECK-yoo-lah	Vulpeculae	vul-PECK-yoo-lay

Things really get crazy when the Latin genitive form of a constellation is needed for a star name. For example, Rigel's other name is Beta Orionis. You'd think you could just attach the "iss" sound to Orion and you'd be in business. But no, it's pronounced BAY-tah OH-rye-OH-niss. Abruptly switching the stressed syllable is a major nuisance, and most of the constellations you managed to pronounce correctly suddenly get a bewildering shift of emphasis when the genitive is used.

Double-worded constellations often have *both* names altered, a twin headache: Ursa Major becomes Ursae Majoris (UR-say mah-JOR-iss). And since the genitive can involve dropping the last one, two, or three letters and then adding -ae, -ii, -oris, -ei, -ulis, -onis, -entis, -orum, -alis, -tis, -icis, -acis, or any of a half dozen other suffixes to the various constellation names, there's almost no choice but to sit down and memorize them as if prepping for a medical school exam.

I've heard some professional astronomers evade the problem altogether by skipping the genitive and saying hybrid things such as "Delta Gemini." They know the meaning will be conveyed, and they've simply given up trying to combine astrophysics with Latin 101.

OTHER GREMLINS

Comet names are commonly mispronounced, mainly because nobody's an authority on a surname except for the person to whom it belongs. So Comet Hyakutake was expressed in a dozen ways, and few tried to mimic the exact Japanese inflection to match the ya-ku-ta-kay family name. Halley's Comet is likely to be permanently spoken as "HAY-lee" thanks to the '50s rock and roll group Bill Haley and his Comets. People may have forever phonetically altered the name of the British astronomer (who probably pronounced his name HAL-ee). After those comets, and previous ones such as Kohoutek and Ikeya-Seki, Hale-Bopp was no small blessing. With a pair of one-syllable names, we finally had a comet that was immune from being mispronounced.

Meteor showers sometimes throw announcers for a loop because now the constellation's possessive form is used. But they're actually easy: For the Geminids, Perseids, Leonids, and Orionids, simply keep the basic, original pronunciation.

Finally we come to the touchy issue of local dialects. How many, for example, clearly enunciate the "t" of "Jupiter?" It's proper to do so, but it sounds a bit affected outside of the British Isles. In the New York area everyone says Jupider, but elsewhere the "t" is simply buried a bit, for vocal ease, and it's hard to quibble with that.

In fact, most of us are involved with astronomy to have fun, not to feel pressured or intimidated by the need to speak the queen's English. Paradoxically, I believe that taking the time to learn the right pronunciations relieves rather than promotes anxiety. Many, I suspect, avoid speaking about their celestial passion simply because they're afraid to sound ignorant. Confidence in one's ability to say it right may well translate into a freedom and desire for more discussions about things astronomical.

And once that happens, the SKYE's the LIM-it.

Frequent contributor Bob Berman, author of the new book Cosmic Adventure, *pronounces his name BOB BURR-man.*

THE SKY SHOW

Bright planets and two comets keep observers busy during the waning days of summer.

by Martin Ratcliffe and Alister Ling

A comet visible with a pair of ordinary binoculars attracts observers in August and September. Comet Lee (designated 1999 H1) was discovered at the Anglo-Australian Observatory by night assistant Steven Lee on April 16, 1999.

After rounding the sun on July 11, Comet Lee swung into the morning sky as a binocular object for most of August and now September. While the comet's brightness of 8th magnitude does not compare to Hale-Bopp, it does give observers a glimpse of what most typical comets look like.

Watch the tiny object move from night to night. Like most comets, this one has a frozen nucleus surrounded by an envelope of gas released by the sun's radiation. Comet Lee will soon return to the depths of space, but for a brief time, observers on Earth have a chance to glimpse this wispy visitor to the inner solar system.

Look for Comet Lee to traverse the northern regions of Auriga during the last two weeks of August. It shines at a respectable magnitude 7.8 and passes a few degrees northwest of the dim open cluster NGC 2281 around August 18. By September 25, it moves into Perseus and lies close to the Double Cluster (NGC 869 and NGC 884).

Through the month of September, the comet is

Saturn, Venus, Jupiter, and Mercury hover over the horizon. This month, look for Jupiter and Saturn to rise in the evening sky, while Venus begins its stint as the "morning star."

Lee C. Coombs

SEPTEMBER 1999

1 The moon passes 3° south of Saturn, 2 A.M. EDT

2 The moon is at perigee (229,795 miles from Earth), 2:04 P.M. EDT
The moon passes 0.8° north of Aldebaran, 6 P.M. EDT
Last quarter moon is at 6:17 P.M. EDT

7 The moon passes 8° north of Venus, noon EDT

8 Mercury is in superior conjunction, 11 A.M. EDT
The moon passes 1.1° north of Regulus, 11 A.M. EDT

9 New moon is at 6:02 P.M. EDT

16 The moon passes 7° north of Mars, 6 A.M. EDT
The moon is at apogee (251,277 miles from Earth), 2:41 P.M. EDT

17 Mars passes 3° north of Antares, 3 A.M. EDT
First quarter moon is at 4:06 P.M. EDT

20 The moon passes 0.7° north of Neptune, 6 P.M. EDT

21 The moon passes 0.6° north of Uranus, 4 P.M. EDT

23 Autumnal equinox is at 7:31 A.M. EDT

25 Full moon is at 6:51 A.M. EDT

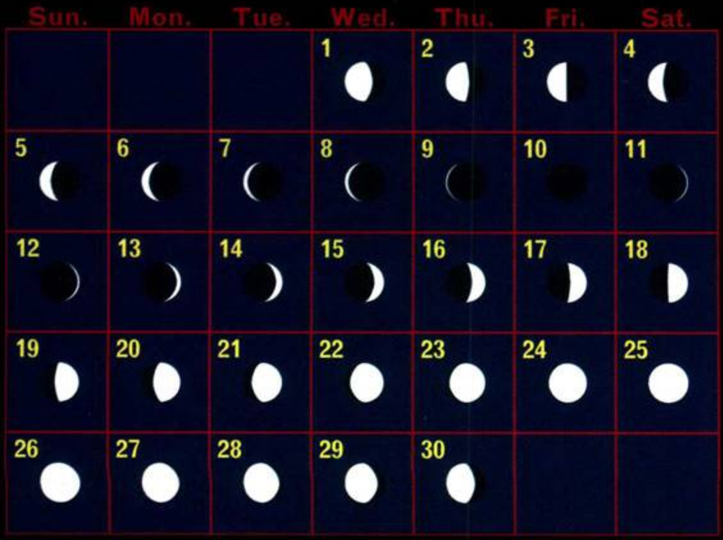
26 Venus is at greatest brilliancy (magnitude –4.6), 11 A.M. EDT

27 The moon passes 4° south of Jupiter, 9 A.M. EDT

28 The moon passes 3° south of Saturn, 8 A.M. EDT
The moon is at perigee (227,578 miles from Earth), 12:43 P.M. EDT

29 The moon passes 1.0° north of Aldebaran, midnight EDT (page 66)

30 Mercury passes 1.7° north of Spica, noon EDT



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
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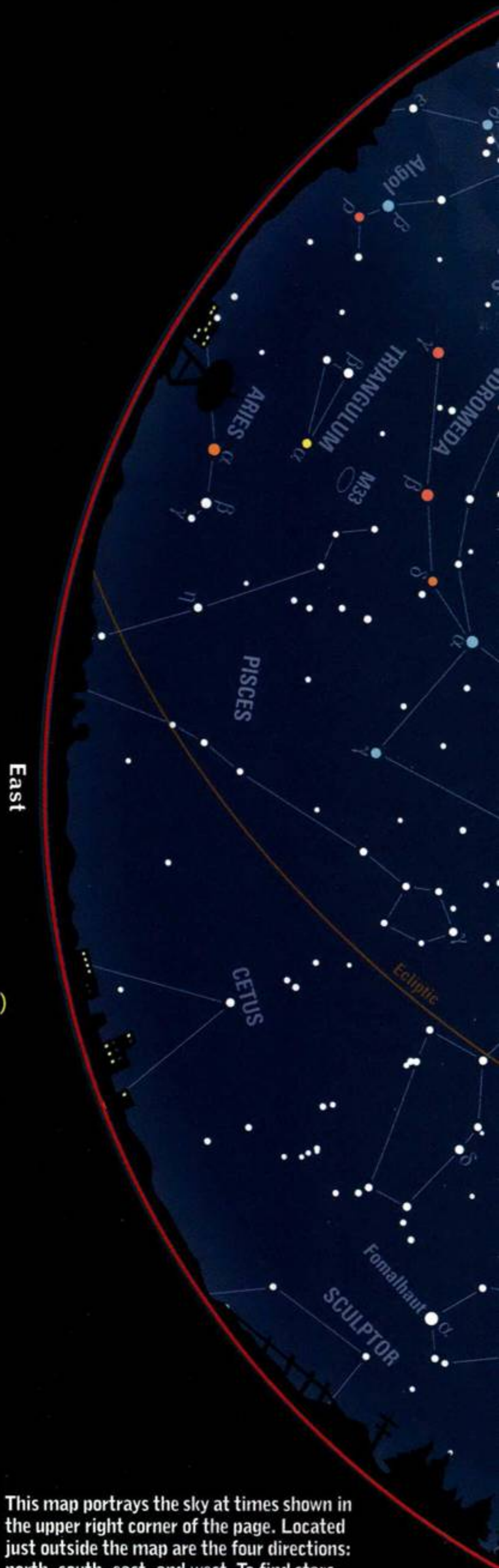
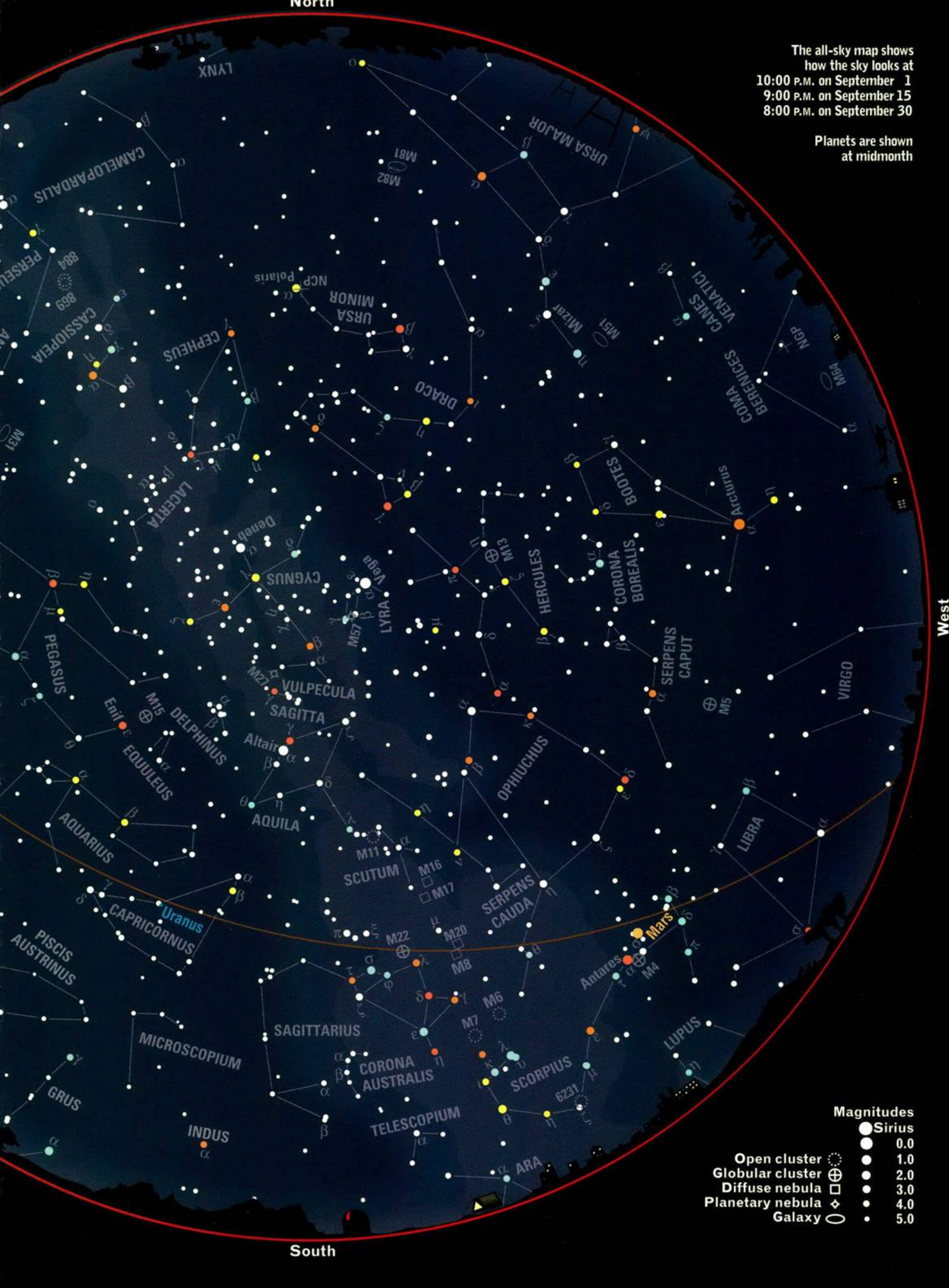
19	20	21	22	23	24	25
26	27	28	29	30		



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead *and orient it so a direction label matches the* direction you're facing. The stars above the map's horizon now match what's in the sky.

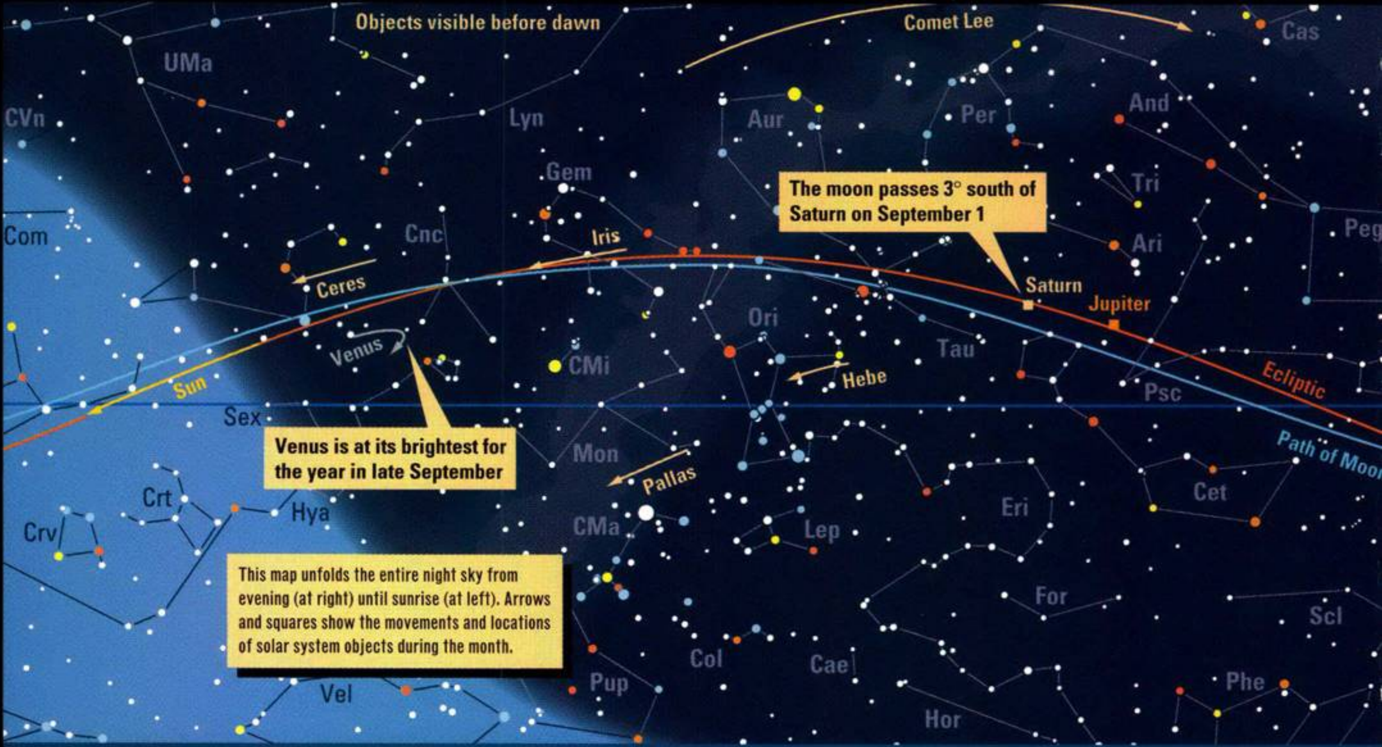


The all-sky map shows
how the sky looks at
10:00 P.M. on September 1
9:00 P.M. on September 15
8:00 P.M. on September 30

Planets are shown
at midmonth

North
South
West
LYNX
URSA MAJOR
M81
M82
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
NCP Polaris
URSA MINOR
CEPHEUS
Mizar
M51
CANES VENATICI
NGP
M64
COMA BERENICES
DRACO
M31
LACERTA
BOOTES
Arcturus
Deneb
CYGNUS
Vega
LYRA
M57
M13
HERCULES
CORONA BOREALIS
PEGASUS
M27
VULPECULA
SAGITTA
SERPENS CAPUT
M5
VIRGO
Enif
M15
DELPHINUS
EQUULEUS
Altair
AQUILA
OPHIUCHUS
AQUARIUS
M11
SCUTUM
M16
M17
SERPENS CAUDA
LIBRA
Uranus
CAPRICORNUS
M22
M20
M8
Mars
Antares
M4
PISCIS AUSTRINUS
M6
M7
SAGITTARIUS
MICROSCOPIUM
LUPUS
CORONA AUSTRALIS
SCORPIUS
6231
GRUS
INDUS
TELESCOPIUM
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS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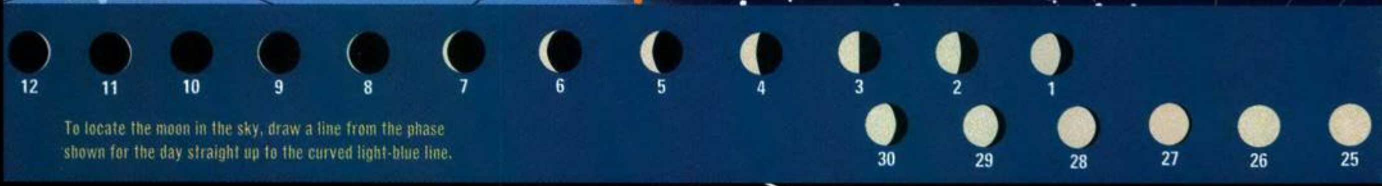
Objects visible before dawn

The moon passes 3° south of Saturn on September 1

Venus is at its brightest for the year in late September

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


12
11
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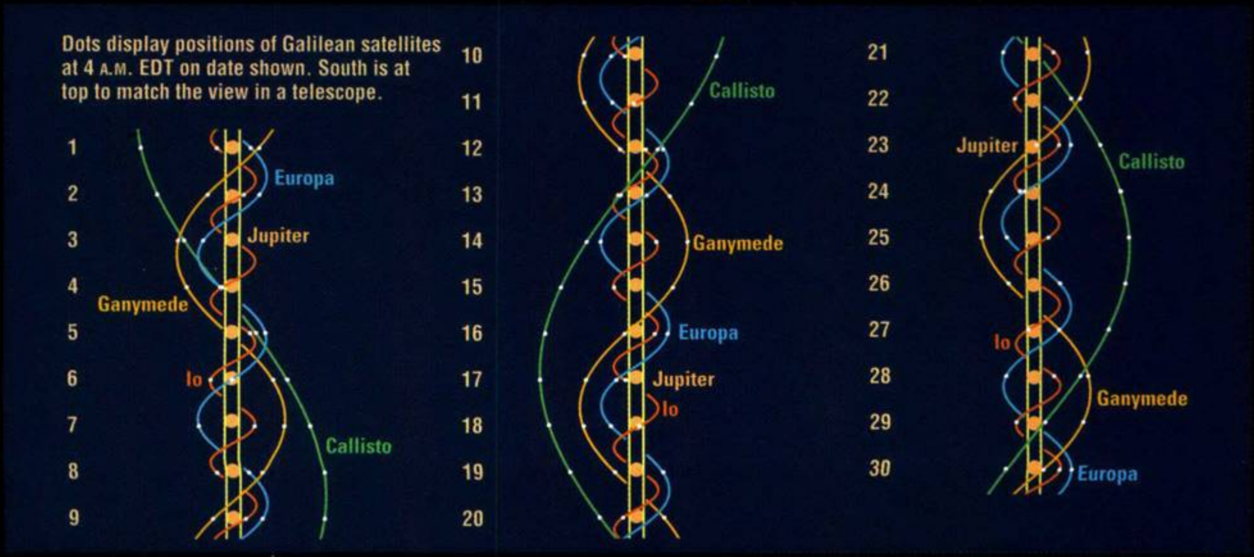
7
6
5
4
3
2
1
30
29
28
27
26
25

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

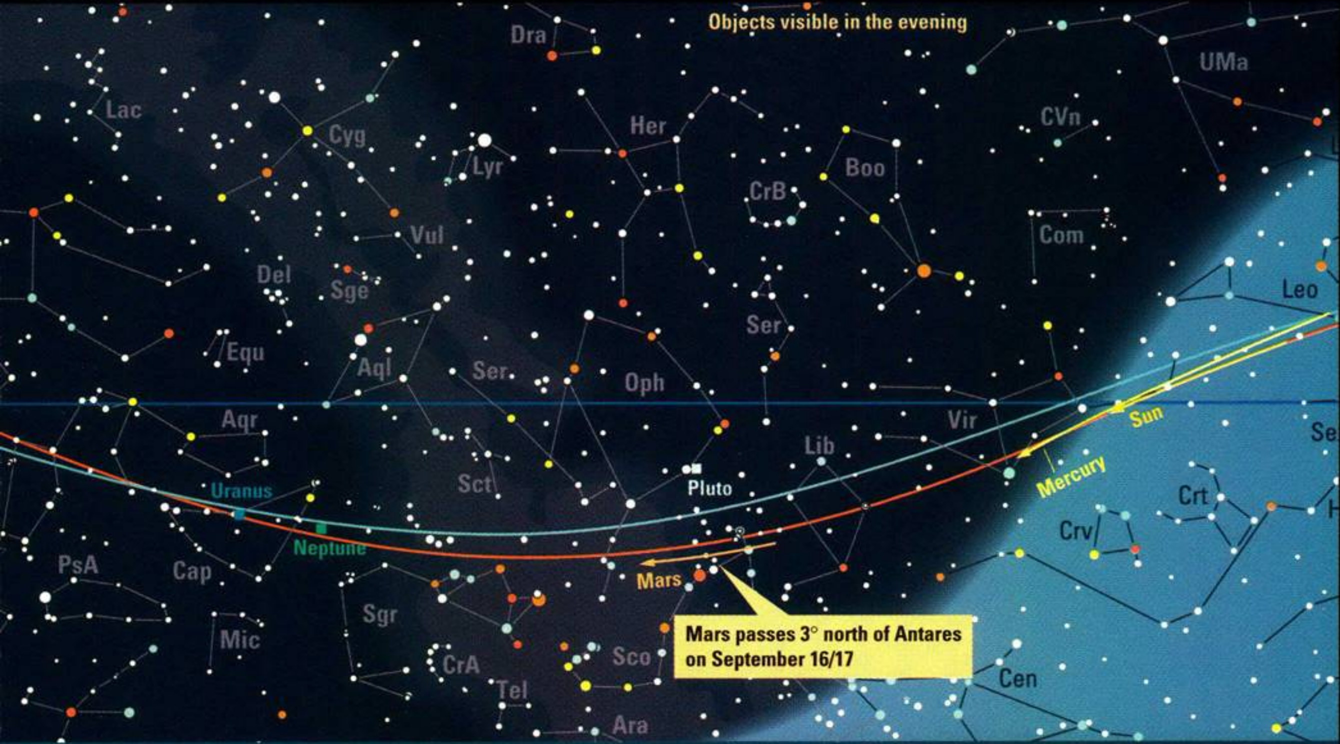
PLANETS	MERCURY	VENUS	VENUS	MARS
Date	September 30	September 1	September 30	September
Magnitude	−0.4	−4.3	−4.6	0.4
Angular Size	5.0"	54.6"	36.0"	7.4"
Illumination	90%	5%	30%	86%
Distance (AU) from Earth	1.335	0.306	0.463	1.268
Distance (AU) from Sun	0.460	0.727	0.724	1.416
Right Ascension (2000.0)	13h21.4m	9h22.4m	9h43.6m	16h22.9m
Declination (2000.0)	−9°02'	6°52'	9°40'	−23°25'

JUPITER'S MOONS



Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view in a telescope.

Objects visible in the evening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Lib
Mercury
Uranus
Sct
Pluto
Crt
Neptune
Crv
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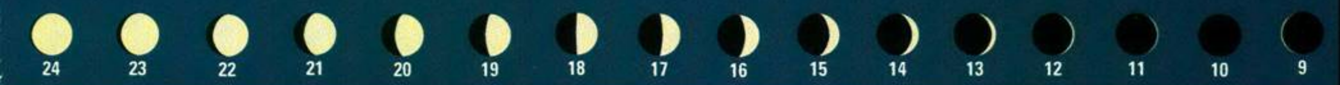
Cen
Ara

Mars passes 3° north of Antares on September 16/17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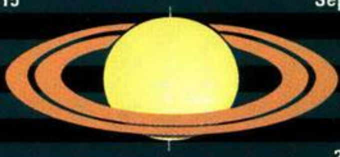
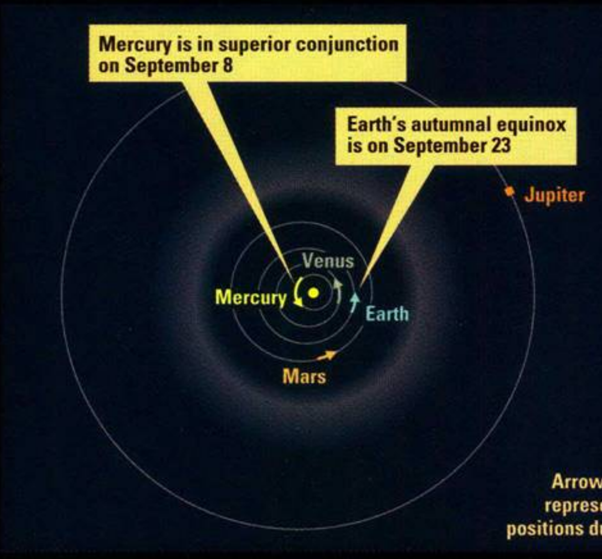


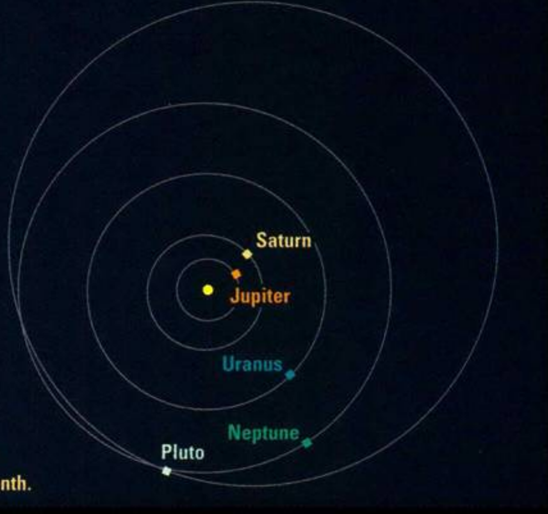
	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
15	September 15	September 15	September 15	September 15	September 15
	–2.8	0.1	5.7	7.9	13.8
	47.3"	19.3"	3.7"	2.3"	0.1"
	100%	100%	100%	100%	100%
	4.167	8.598	19.114	29.467	30.411
	4.955	9.208	19.913	30.124	30.192
	2h10.1m	3h00.9m	21h04.5m	20h16.0m	16h32.0m
	11°32'	14°29'	–17°28'	–19°30'	–10°32'

THE PLANETS IN THEIR ORBITS


Jupiter
Venus
Mercury
Earth
Mars

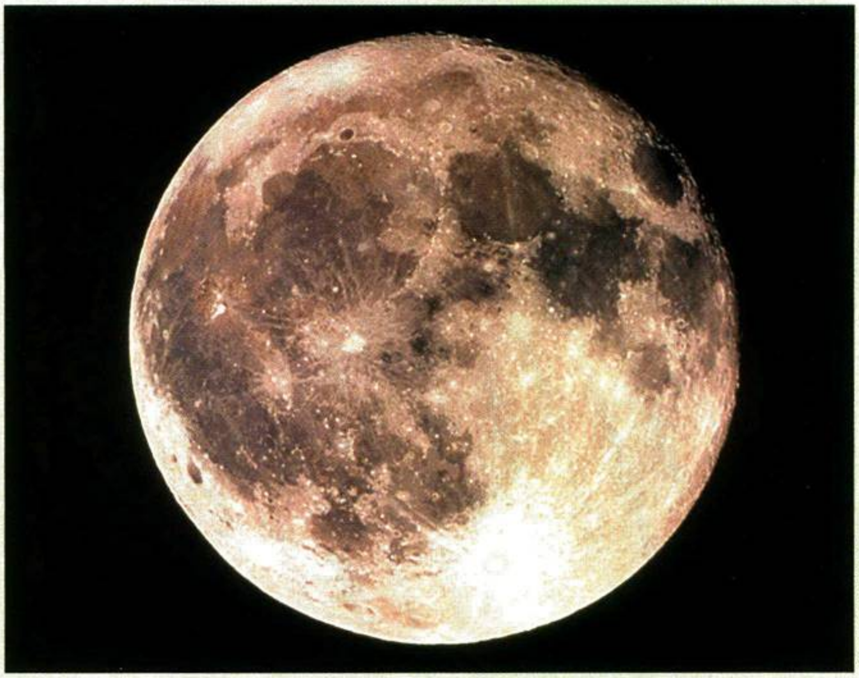
Mercury is in superior conjunction on September 8

Earth's autumnal equinox is on September 23


Saturn
Jupiter
Uranus
Neptune
Pluto

Arrows and dots represent planets' positions during the month.

First Views: A Flooded Lava Plain — The Moon's Grimaldi



Bill and Sally Fletcher

The changing play of sunlight across the moon's face is a never-ending source of delight to lunar observers. Each night as the moon waxes and wanes, jagged shadows retreat, yielding to the bright sunlight that pours across the plains to reveal the tops of distant mountains formed by crater rims and central peaks.

A prominent basin called Grimaldi lies in the moon's southwestern quadrant near the limb — which Northern Hemisphere observers would call the lower left. It is the crater named in honor of the 15th-century Italian astronomer Francesco M. Grimaldi, who authored a map of the moon in the decades following the invention of the telescope.

A few billion years ago, Grimaldi basin became flooded with lava, which then solidified into the smooth floor we see today. Grimaldi is one of the smoothest places on the moon. It shows little detail and only during periods of sunrise. So don't miss this opportunity.

Sunrise over Grimaldi begins on September 23. By September 24, the basin is completely lit, with the exception of some really interesting shadow areas around the rim.

Start your tour with Grimaldi's relatively smooth, flooded basin. Try to spot Rimae Grimaldi, a system of rills roughly 143 miles (230 km) in length on the basin's floor. Also view the jagged terraces that surround the crater. Here a jumble of light and dark reveals further detail.

Grimaldi has two crater rims. Its inner wall is some 138 miles (222 km) in diameter, while the much larger and heavily damaged outer wall has a diamter of roughly 267 miles (430 km).

As the moon orbits Earth, we get to see slightly more or less of the limb areas because our viewing perspective changes. This effect is called libration, and Grimaldi is one of the features that reveals this effect. On September 25, at full moon, note how far the basin is from the limb. Every couple of days during the next week, Grimaldi will appear to slowly get squished against the limb.

circumpolar from the northern half of the United States. It has dimmed to magnitude 8.6, stands high above the horizon at midnight, and remains visible all night.

Telescopes will provide a better view than binoculars as the comet fades. (The details of Comet Lee's path listed here were based upon an ephemeris supplied at the time of publication. These details may change slightly as the comet's orbit is refined; visit www.astronomy.com for the latest information.)

While you're out observing Comet Lee, remember to catch a glimpse of Comet Tempel 2, which wanders very close to the Lagoon Nebula (M8) in Sagittarius this month.

As the sun goes down, Mars becomes visible low in the south. It rapidly approaches its rival, the reddish star Antares in Scorpius the Scorpion, and dims to magnitude 0.5 — still brighter than its stellar neighbor. On September 6, Mars passes one-quarter of a degree north of the bluish 2.3-magnitude star Delta (δ) Scorpii. The pair is visible in the same telescopic field of view and provides an attractive color contrast for naked-eye observers as well.

Surface details on Mars are now hard to come by. The planet's tiny 7" disk, along with the atmospheric turbulence produced by viewing the planet low in the sky, makes seeing detail difficult. Mars and the bright globular cluster M80 lie in the same field of view 2⁄10 of a degree apart on September 12. Three days later, the planet skims past Rho (ρ) Ophiuchi, a magnitude 5.0 star made famous by the surrounding nebula seen in long-exposure photographs. If the thought of photographing this pairing entices you, keep in mind that a 6-day-old waxing moon floats only 7° north-northwest of Mars.

The following day, on September 16, Mars lies a bit less than 3° north of Antares. On September 28, Mars pairs with a dim fuzzy glow. Don't think you've discovered a comet: that fuzzy patch is the 9th-magnitude globular cluster NGC 6284 in Ophiuchus.

When twilight has vanished, Capricornus the Sea Goat stands high in the southeastern sky. This constellation is rather dim, containing no stars brighter than magnitude 2.9.

Capricornus is an exception to the Greek letter-naming rule for its stars. Usually the brightest star in a constellation is designated Alpha (α), the second brightest is Beta (β), and so on. This isn't true for Capricornus. Delta Capricorni is the brightest star. Delta is variable and can occasionally dim to the magnitude of the second brightest star, Beta Capricorni. The third brightest is Alpha Capricorni (a fine optical double with each individual star multiple as well). The fourth brightest star in the constellation is Gamma (γ) Capricorni.

Neptune, the eighth planet from the sun, lies 7° south of Alpha Capricorni and can be picked up in small telescopes on September evenings. A waxing gibbous moon lies 2° east of Neptune on September 20. The 7.9-magnitude planet appears as a dim bluish disk just over 2" across.

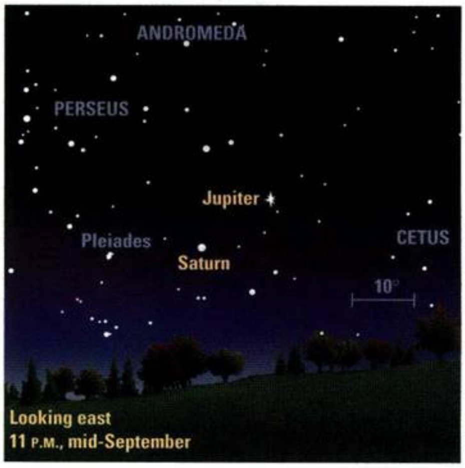
Midway across Capricornus lies the seventh planet in our solar system, Uranus. If you have never seen Uranus before, this is the time to find it. The planet lies very close to the sixth brightest star in Capricornus, magnitude 4.1 Theta (θ) Capricorni. Because Uranus shines at magnitude 5.7, Theta will appear to have a companion for a week before and after September 2. On that evening, Uranus lies a mere

Jupiter and Saturn Rule

Finally, Jupiter and Saturn rise before 10 P.M. The largest planets in the solar system will constitute a bright pair over the next few years. They also stand out because they lie in a relatively star-poor area of the sky.

Do you remember when you first saw Jupiter or Saturn? It was two jovian orbits ago, in 1975, when I was looking at bright stars in my small telescope when I accidentally "discovered" Jupiter. What a sight it was to see the bright Galilean moons accompanying the round disk. In those days, I didn't even see the two main cloud belts. Over time, the more I looked, the more I saw. I was training my observing eye without even knowing it.

Chances are you'll be looking at Jupiter as early in the evening as is possible. Although that's fine for a fast visit, try to wait until midnight. At that time, less atmospheric turbulence gets in the way of your view. Early autumn is often a time for steady atmospheric conditions that yield excellent seeing.



All illustrations: *Astronomy*/ Elisabeth Rowan

Extended periods of fine weather are just the ticket for sharpening your planetary observing skills. Start by picking out features on the planet's surface. Jupiter's belts, bands, and festoons can all be spotted in a modest scope with a trained eye. Later in the evening, turn your sights to Saturn and its majestic ring system.

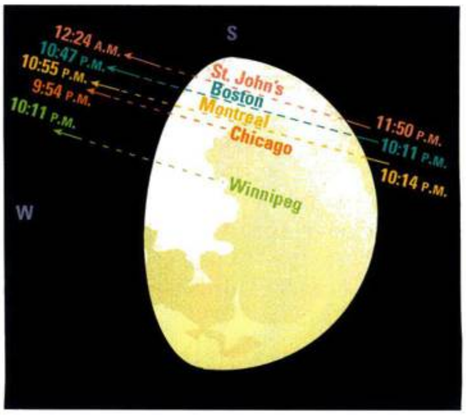
Aldebaran's Last Hurrah

For the past few, years the moon has been crossing in front of the bright star Aldebaran. This month, it does so again, but for North American observers, it's the last time until 2015. In fact, for those in the western U.S. it's already too late. The September 29 occultation isn't visible there.

Why is this the last such occultation for 16 years? The moon's orbit gradually shifts over an 18.6-year cycle. This means it will soon glide past Aldebaran without passing in front of it.

The moon is a few days past full for this occultation, which means that Aldebaran will be covered by the moon's bright limb. This will pose a challenge for many observers since the moon's bright glare may overshadow the star's light. Some 40 minutes after Aldebaran's disappearance, the star reemerges from behind the dark limb. The reappearance is always sudden, so use a lower power eyepiece to give you a wider field of view.

The diagram below will help you estimate when the event occurs for your area. Detailed times can be found at www.lunar-occultations.com/iota. Only those in the northeast will be able to watch the disappearance, and if you live southwest of a line from Cape Hatteras through Thunder Bay on Lake Superior, you're out of luck.



7' south of the bright star. The twosome will be easily visible in the same telescopic field of view.

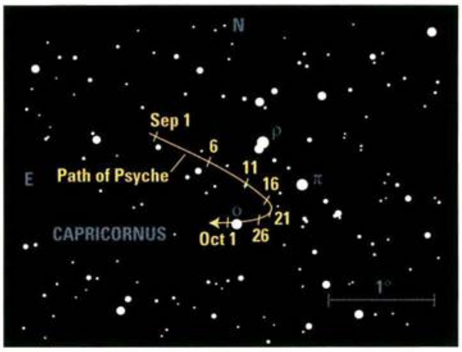
Rising in the east two to three hours before midnight are the two giant planets of the solar system, Jupiter and Saturn. The pair rests only 12° apart among the stars of Aries the Ram. Jupiter leads the way by rising first. At magnitude –2.8, it's blazingly bright and unmistakable as it rises over the eastern horizon at approximately 10:20 P.M. local time on September 1. By the end of the month, it's up two hours earlier.

Jupiter reaches opposition on October 23, so its apparent size is about as large as it will get all year, roughly 48" across. This event allows even small telescope users to see detail in the planet's atmosphere. The most prominent features are its dark equatorial belts. Which one appears to be the darkest?

Perhaps most obvious to casual observers are the four bright moons that dance nightly around the jovian planet. Io never strays far from its parent, orbiting Jupiter every 1.8 days — even two views an hour apart will betray its motion. Europa takes 3.6 days to orbit, while Ganymede, the largest of the four Galilean moons, makes an orbit in one week. Second in size to Ganymede is Callisto. This moon orbits Jupiter slowly, once every 16.7 days.

Our view of the moons' orbits is nearly edge on. This allows observers to view each moon's passage in front or behind Jupiter. Every now and then, a transit across the face of Jupiter reveals a shadow. Perhaps a moon will be occulted by the planet's

Asteroids Are Hip



Now that the NEAR spacecraft is on its way to a rendezvous with the asteroid Eros, these oddly shaped rocks are enjoying a rise in popularity. The 16th asteroid to be discovered, Psyche, was at opposition on August 2 with a magnitude of 9.5. Though it has dimmed slightly to magnitude 10, it's still the brightest asteroid in the September evening sky. This makes Psyche a relatively easy object for backyard observers to find in a modest telescope.

Start your hunt at the beautiful wide double star Alpha¹ (α¹) and Alpha² (α²) Capricorni, the beacon at the upper right corner of the constellation Capricornus the Sea Goat (see the Sky Dome map pages 61 to 64). Then head south and slightly east past bright Beta (β) Capricorni. Stop at 5th-magnitude Rho (ρ) Capricorni.

The chart at the upper left shows a handful of stars at 10th magnitude, the same brightness as Psyche. If it's not obvious which "star" is the asteroid, sketch the field of view, wait a day or two, then look again to see which one has moved.

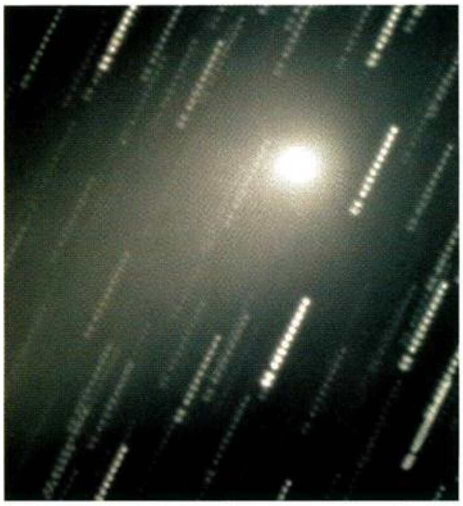
Discovered by the Italian astronomer Annibale De Gasparis in 1852, 16 Psyche is 165 miles across (260 km). The asteroid is named after the beautiful princess who married Eros (Cupid). According to the myth, Psyche had two sisters. All were great beauties, but Psyche was more radiant. Jealous Aphrodite sent her son Eros to inspire an irrational love of some object in Psyche. Instead, he fell in love with her.

A North Circumpolar Comet

Comet Lee (C/1999 H1) graces northern skies as it becomes a circumpolar object for northern latitudes. Though it passed 66 million miles away from the sun (perihelion) on July 11, the comet's closest approach to Earth occurs on September 30, roughly 76 million miles away.

The map below charts Comet Lee's path through the beginning of the month, when the moon's glare will not interfere with the view. At magnitude 8.2 on September 1, the comet should be an easy binocular target. It gradually dims over the following weeks, closing out the month at magnitude 8.7 on September 30.

Though the moon will be bright, look for Comet Lee near the Double Cluster in Perseus on September 25 – 27.



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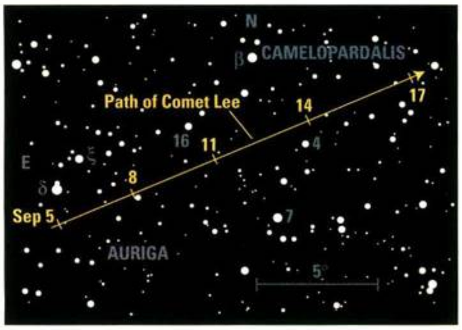


Observer's Challenge: A Polarized Egg Nebula

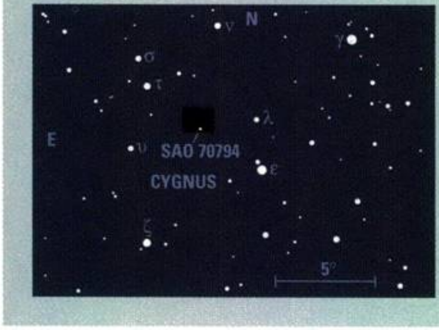
STScI/NASA/R. Sahai/J. Trauger/JPL

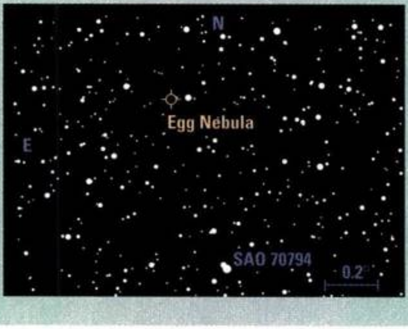
The Egg Nebula (CLR 2688; 21h2.3m 36°42' [2000.0]) is a curious beast. Recent Hubble Space Telescope images reveal a complex object. The Egg Nebula appears to be a very young star enshrouded in a cocoon of gas with an equatorial dark cloud of dust and illuminated jets spewing from its poles. In short, it's a bipolar planetary nebula, a dying ordinary star. The Hubble photo shows what may be dozens of expanding gas shells.

The Egg Nebula glows meekly at about 12th magnitude, and because it is only a few arcseconds across, it has a relatively high surface brightness, almost like a star. This means that a 12-inch telescope from the suburbs can reveal it as a faint "star."

It's a moderate challenge to point your scope in exactly the right place. Start at Epsilon (ε) Cygni, the left arm of the Northern Cross asterism in Cygnus. The Egg lies eight moon diameters (4°) away. At first, all that might be seen is a faint star, but even in poor seeing, I could detect a small shell of faint nebulosity with my 12.5-inch scope at 250x. The nebula's southern component is fainter than the northern one, faint enough that you might not see it.

Oddly, the Egg Nebula emits strongly polarized light. Even if the only polarizers you own are sunglasses, chances are you will be able to confirm this effect. Few other deep-sky objects display this remarkable property. By far the best trick of the trade for this type of challenge is a dark cloth or towel. Place it over your head and eyepiece to block out stray light. If you have a screw-in polarizing filter, simply rotate your eyepiece, otherwise, rotate your polarized sunglasses. Watch the Egg brighten and dim while the other field stars remain unchanged.





limb as it wanders behind, or it may disappear into the shadow behind Jupiter. Currently Callisto avoids such events, passing above or below Jupiter as seen from Earth.

Forty minutes after Jupiter rises, the Ringed Planet, Saturn, appears over the eastern horizon. By the final week of September, Saturn shines at magnitude 0 and lies 15° southwest of the Pleiades (M45), or Seven Sisters, in Taurus the Bull.

While Jupiter shows off its moons and belts, Saturn dazzles with its ring system. The two gas giant planets are similarly sized, but Saturn lies at double the distance, 797.9 million miles from Earth. Its disk, therefore, appears to be half the size of Jupiter's. Fortunately, its expansive ring system makes up this size difference. Currently, Saturn's southern face is tilted 20° in our direction. Early in September, it will still be possible to view the shadow of Saturn's globe on the rings. This will become more difficult as Saturn reaches its November 6 opposition.

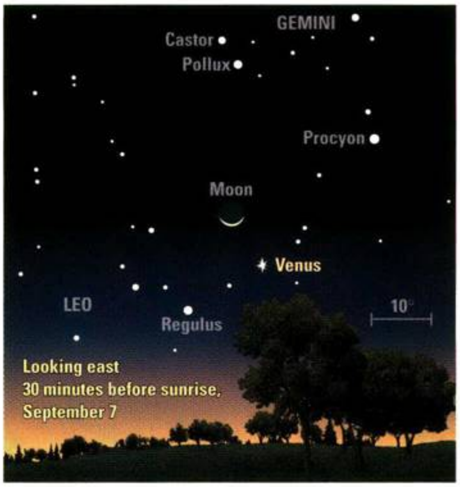
As the pair of bright planets stands above the eastern horizon, the Great Square of Pegasus can be found high in the southeast. It rises with the watery constellations of autumn. These include Aquarius the Water-bearer, Cetus the Whale, and Pisces the Fish.

Take particular note of Cetus. The famous variable star Mira (Omicron [o] Ceti) is nearing its maximum brightness after months of below naked-eye visibility. Mira can reach magnitude 3, though it has sometimes brightened further. Binoculars will show the star's ruddy color. Every seven to ten

Venus Returns as a "Morning Star"

After a couple of weeks away from the evening sky, a planetary favorite, blazing Venus, vaults high into the morning sky. How does Venus do this? It's like being in a slower car that had a head start and watching a faster car catch up to you. It's behind you a long time, then all of a sudden it speeds past and stays in front. Because Venus's orbit is smaller than Earth's, it suddenly appears to catch up and move rapidly away from the sun.

Venus should be prominent in the east by September 10. To its right, Sirius is the brightest star in the sky at –1.4 magnitude. In comparison, Venus reaches its greatest brilliancy at –4.5 on September 26, a remarkable difference. Remember that smaller magnitudes indicate brighter objects. The sun shines at magnitude –26.



Looking east
30 minutes before sunrise,
September 7

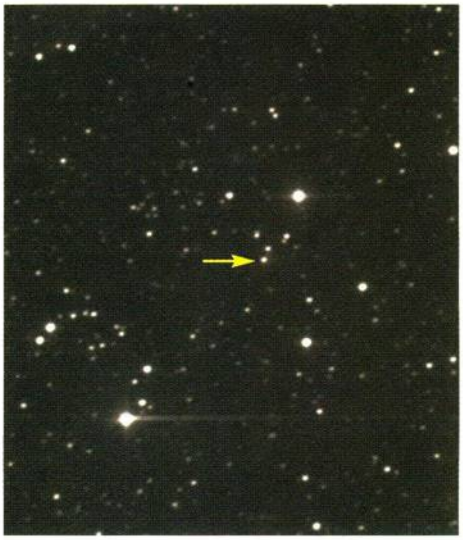
On September 8, a pretty crescent moon rests 12°, almost two binocular fields, to the left of Venus. In October the pair will be higher in the sky.

Find Comet Tempel 2

There's not much that can beat watching a bright comet through the eyepiece. Although not as famous as some of its solar system siblings, periodic Comet Tempel 2 certainly makes up for lost time as we wait for the next "big one." This month, the 9th-magnitude interloper crosses one of the most photogenic areas of the summer sky, the Sagittarius region of the Milky Way. The event should be quite beautiful. If you want to capture it on film, try using lenses between 135mm and 300mm.

Observing comets is similar to observing deep-sky objects. For both types, you need a fairly dark sky that offers good contrast (a nice black sky that reveals the fine wisps of a nebula or jets in a comet's tail).

To see Tempel 2, go out before September 12. After that date, the waxing moon begins to spray light across the evening sky, washing out the contrast. You'll also want to set your equipment up by the time darkness arrives. Tempel 2 is relatively low in the sky and will continue to fall as the evening progresses, which will again reduce contrast. If you wait too long to find the comet, you may not see it at all.



Tim Puckett

It's a good idea to begin your observations at low magnification, then gradually boost the power. This allows you to become familiar with the comet's shape and texture. Once you've attained high power, keep an eye out for any jet activity in the comet's nucleus. By the time you start increasing the power, your dark adaptation will allow you to pick out faint tail structures.

days, try estimating its brightness relative to other stars. When do you think maximum light occurred?

Rising in the northeast at the same time as Pegasus are Cassiopeia and Perseus. This region of the sky is a fine area for touring with binoculars. Seek out the Double Cluster midway between the two constellations. The Double Cluster is just one of several clusters in this rich region.

After midnight, the stars of winter appear over the eastern horizon. Orion the Hunter is up by 2 A.M. local time. Gemini the Twins follows it to the north. The predawn hours also bring the "morning star," Venus, above the horizon. The planet rises some two hours before the sun. At –4.4 magnitude, it dazzles. Telescopically, Venus sports a 12-percent crescent that grows to 30 percent by the end of September.

As the sun rises along the East Coast on September 23, it does so exactly due east, for this is almost the moment of the autumnal equinox. The sun, in its annual path around the sky, crosses the celestial equator on its way into the southern sky. For the next six months, shorter days and cooler temperatures will dominate the Northern Hemisphere. Conversely, warmer temperatures and longer days are beginning in the Southern Hemisphere. The precise crossing takes place at 7:30 A.M. Eastern Daylight Time. ◼

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

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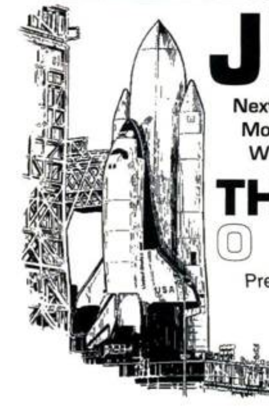

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By Philip S. Harrington

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Crater

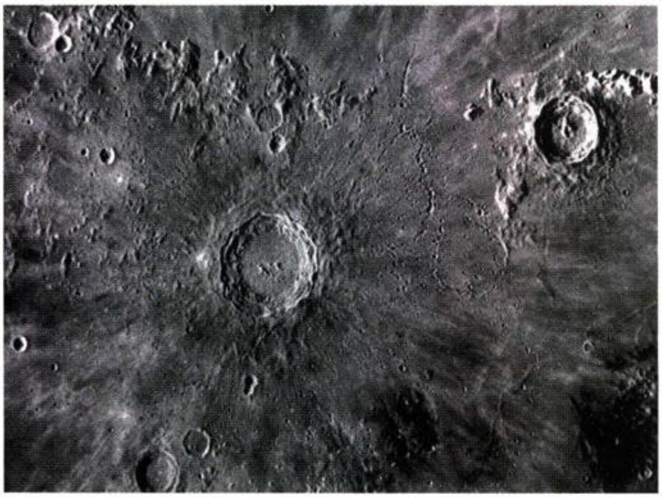
Make yourself looney by viewing craters and

Imagine yourself in medieval Britain on a peaceful, warm summer's evening in the late 12th century. Frogs sing their nightly tunes while gnats hover about your head. As you swat them from your face, the moon, just a few days past new, comes into view. What a fine night. Then, in a sudden flash, the moon's waxing crescent appears to split in two. Is the world coming to an end?

On a June evening in 1178, five British monks saw the moon's northeastern limb sprout a cloud of "fire and hot coals." Their account was chronicled in the extensive records of another monk named Gervase in Canterbury, England. Today, meteor scholars have identified this event with the 125,000-megaton explosion that carved the crater known as Giordano Bruno at roughly 36° N, 102° E on the moon's northeastern limb.

The study of craters began in 1609 when Galileo Galilei pointed his modest telescope toward the moon. He quickly recognized that the circular areas he called "spots" were actually depressions. As the moon's phase changed, Galileo observed the raised crater rims catching the sun's rays before the crater floors.

Nearly 60 years after Galileo looked at the moon, Robert Hooke published his book *Micrographia*. In it, he suggested two possible origins for lunar craters, internal volcanic activity or impact from an external object. Though Hooke had experimented with musket balls and mud in making impact craters, he believed that lunar craters probably had a volcanic origin. At that time, interplanetary space was thought to be empty, and Hooke couldn't imagine where the impact objects came from.



Copernicus (center) is a complex, young crater visible with binoculars on the northern hemisphere of the moon. Lick Observatory

Today, we know that most of the moon's surface formed more than three billion years ago when the solar system was heavily populated with asteroids. These remnants of the solar system's formation were "swept up" by the planets and their moons. Earth was also hit many times, but water, life, and atmospheric and geologic processes have eroded many of Earth's craters until they are barely recognizable today. Because most of those processes do not affect the moon, its surface has remained relatively unchanged since the end of the period of heavy cratering.

Impact craters are a natural lure for children. The spectacular way in which they form spurs a child's imagination, while the features that result are easily spotted in the most modest equipment. Anyone can look up at the full moon and identify its largest seas and craters. With a pair of binoculars, lunar mountain ridges, crater rims, and central peaks come into focus. Observing the moon is an ideal entry point into astronomy for children — particularly because most notice its "changing face" at a very young age. I've heard a two-year-old refer to the crescent moon as a "broke" moon. He was accustomed to seeing a much larger phase.

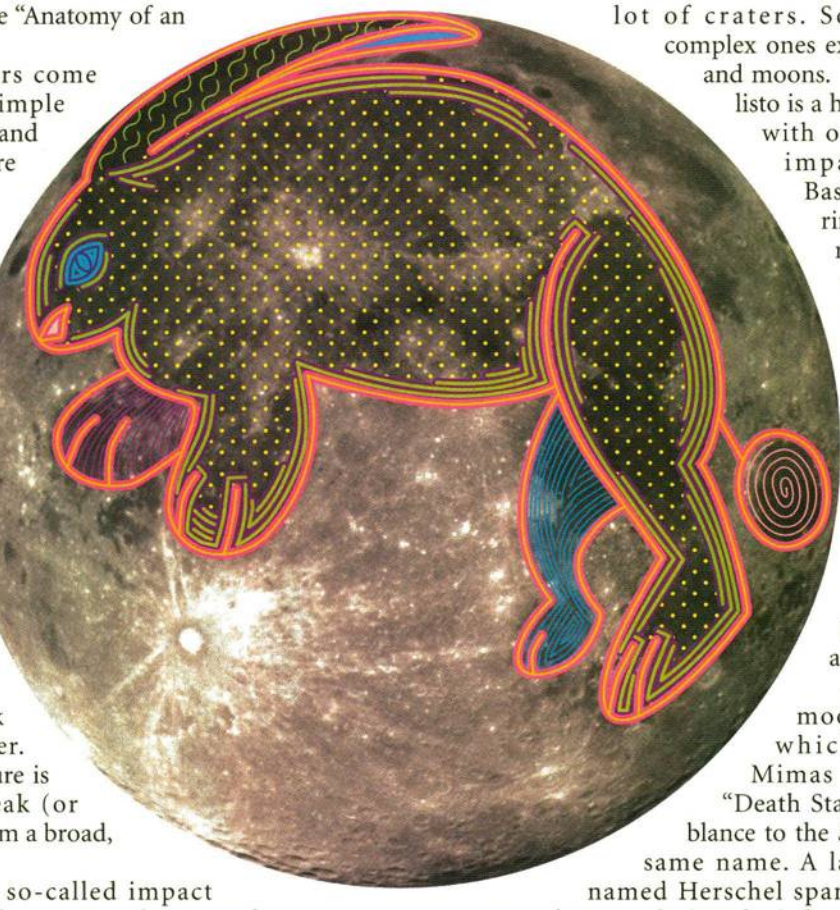
Kids' Corner

Crazy

even making your own. **by Andrea Gianopoulos**

Crater Characteristics

Begin your child's lunar lesson with some basic features. The moon holds craters, basins, mountains, rilles, and rays. Each has its own attributes, but all are related to impacts in some way (see "Anatomy of an Impact," page 75).



Lunar impact craters come in three basic types: simple craters, complex craters, and basins. Simple craters are what most people think of when they visualize a crater. They tend to be bowl-shaped with rounded or small, flat floors. Simple craters also have smooth rims that lack terraces. As crater diameter (measured rim to rim) increases, the resulting features become more elaborate.

Complex craters have scalloped inner walls that formed when unconsolidated rock slumped into the crater. Their most striking feature is an uplifted central peak (or peaks) that protrudes from a broad, relatively flat floor.

Larger still are the so-called impact basins. An interior ring characterizes this crater form, which has three divisions of its own. Central peak basins, such as Compton, have a fragmented ring around a central peak, and they tend to be small. Peak-ring basins, such as Schrödinger Basin on the south-southeastern limb, have a well-developed ring but no central peak. The largest of the crater types is the multi-ringed basins. They generally are more than 250 miles (400 km) wide and can have as many as six concentric inner rings. One of the best examples is Mare Orientale, the Eastern Sea.

The moon isn't the only place with a lot of craters. Some of the more complex ones exist on other planets and moons. Jupiter's moon Callisto is a heavily cratered world with one very prominent impact. The Valhalla Basin has an extensive ring structure that surrounds the central crater. The entire ring basin measures nearly 1,900 miles across. That's more than half of the moon's 3,100-mile (5,000-km) diameter. If Valhalla were placed over the United States, it would stretch just past our borders with Canada and Mexico.

Another scarred moon is tiny Mimas, which orbits Saturn. Mimas is nicknamed the "Death Star" due to its resemblance to the *Star Wars* ship of the same name. A large impact crater named Herschel spans one-third of the moon's 240-mile (390-km) diameter. If the collision that formed this crater had been much stronger, Mimas would have been shattered into pieces.

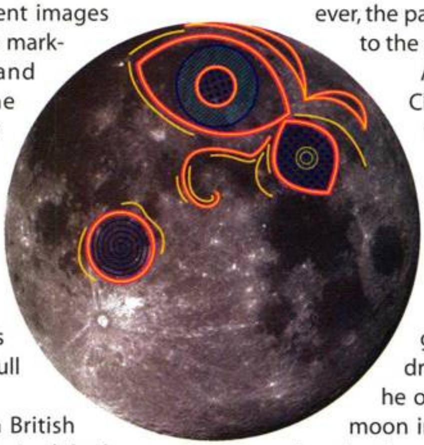
Creating Craters

If you're like me and didn't get enough mud-pie time as a kid, try making a few crater pies of your own. It's guaranteed

What Do You See?

Swiss cheese? Green cheese? Is it Gouda? Well ... we all know the moon isn't made of cheese, even if residents of the "Dairy State" would like to see it that way.

Cheese is just one of the many different images seen in the charcoal-gray, black, and white markings created by various lunar craters and basins. The most famous of these is the "man on the moon," whose face looks like a jack-o'-lantern. But the man in the moon isn't the only figure you can find.



The Native American Aleuts in Alaska see the moon as both a man and a woman. According to the story, the moon man carries his charge across the sky from new moon to full moon, while his wife carries the phases that fall between full and new moon.

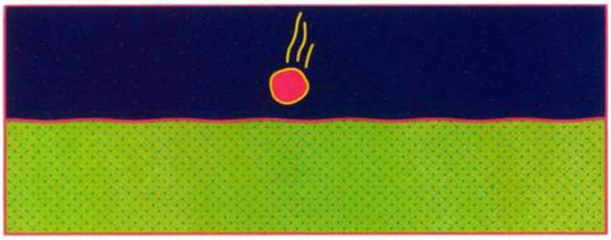
The Native American Haida people in British Columbia see a woman who carries a bucket, while the ancient Greeks believed the full moon was the goddess Selene riding her silver chariot across the sky.

Even children can be spotted on the moon. To the Vikings, the dark lunar maria represent a boy and girl who went up a hill to get a pail of water. Sound familiar? In this story, however, the pair didn't fall down, but were whisked away to the moon instead.

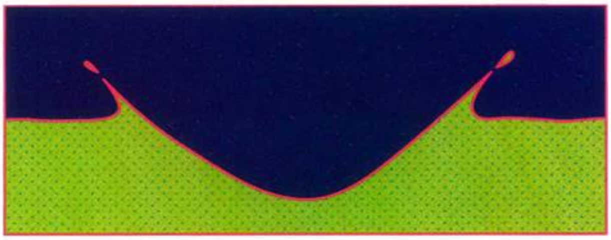
Animal figures have also been popular. The Chinese see a rabbit in the dark areas and a toad in the white. A rabbit may be the most common figure seen on the moon, with cultures in southeast Asia, Korea, and Japan, as well as the ancient Maya and Aztec civilizations all discerning a bunny's form with ears and tail.

So, the next time there is a full moon, go outside and take a look. Have your child draw a picture and/or write a story of what he or she sees "in the moon." There are three moon images shown on these pages to provide inspiration. Send your stories and works of art to *Astronomy*'s Kids' Corner, P.O. Box 1612, Waukesha, WI 53187-1612; or e-mail them to kids@astronomy.com.

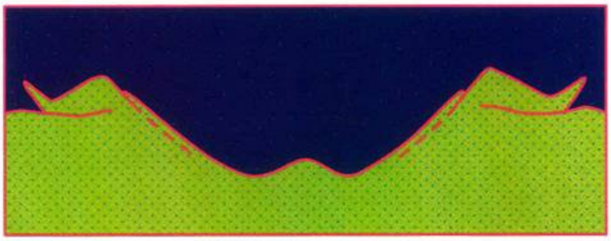
Anatomy of an Impact



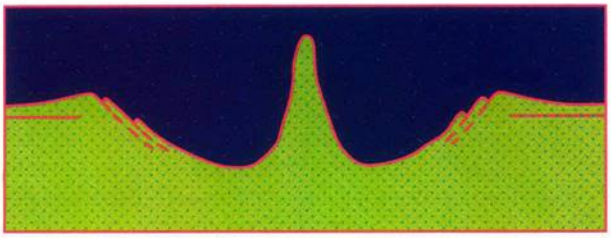
The size, speed, and angle at which an asteroid or comet hits determines the type of crater that forms.



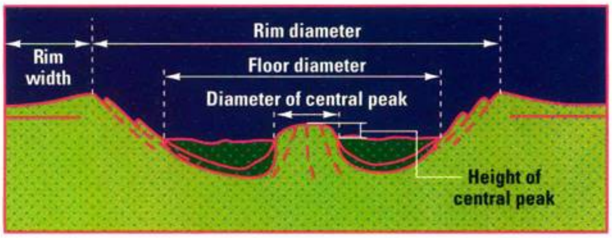
The initial impact creates a bowl-shaped crater and sends material (known as ejecta) out in all directions forming crater rays.



Rebounding debris from the impact forms a central mound. Material falls back into the crater forming terraces along the inner wall.

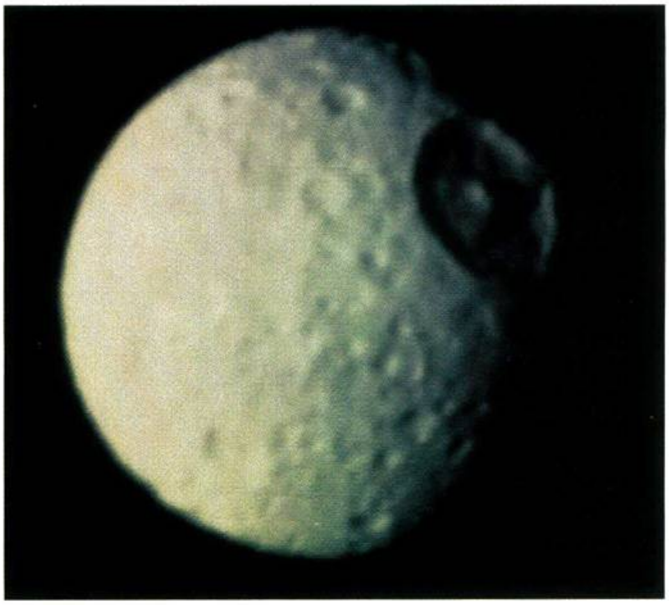


The central peak begins to collapse back into the crater basin due to the force of gravity.



The final crater in this example is similar to the complex crater Tycho found in the moon's southern quadrant.

All moon images by Larry Loechel, all illustrations by *Astronomy*: Terri Field



Above: Saturn's moon Mimas bears a striking resemblance to *Star Wars*'s the Death Star. The Planetary System Astronomical Society of the Pacific

Facing Page: The Aorounga impact crater, created several hundred million years ago, is still visible by space radar above Chad, Africa. JPL, NASA

to be a hit with the kids. You'll need an aluminum pie pan, a metal spoon, a paper cup, water, some fine clay-rich soil or drywall plaster, and newspapers to protect the table and floor from stray impacts (better yet, try this out on the driveway).

Begin by placing some of the soil in the pie pan. Be sure to break up any large clumps and remove all rocks, sticks, and other debris. Add water to the soil, stirring as you go. Continue adding water until your concoction is the consistency of a very thick batter. If you're using plaster, follow the package directions. You may have to add plaster gradually to the water you've placed in your pie pan.

Once you've got the mixture to the proper consistency, scoop a small portion into the paper cup and smooth the surface of the mixture in the pie pan. With your spoon, scoop up a small glob from the cup. Stand above the pie pan and let the glob drop from the spoon. Now, if you're feeling particularly impish, you can go back to your "food-fight" days and fling the glob from the spoon. You'll get extra points for actually hitting the pie pan. For a more dramatic effect, sprinkle the smooth muddy surface with flour or light sand before making the craters. This may help certain features, such as crater rays, stand out in your end product.

Continue making craters by varying the size of the globs and the angle and velocity at which they hit the plate. Once the pan holds craters of different sizes and shapes, let it dry out so you can study it.

Do all the craters have central peaks and raised edges? Are there rays that lead away from the crater? What type of crater formed with a large glob that was dropped from the spoon as compared to one that was flung from the spoon? How do craters formed by small globs differ from those formed by large ones? You can find the answers in your mud-pie moon. A

Andrea Gianopoulos is an associate editor for Astronomy.

Pisces and Cetus

A shipload of galaxies rides high above the watery constellations Pisces the Fish and Cetus the Whale.

by Tom Polakis

JUST BEFORE WINTER'S ONSLAUGHT of storms, autumn typically brings the clearest skies. On the meridian we find a star-poor region of the sky that is often bypassed for the starry Milky Way fields to the north. But Pisces and Cetus do hold some telescopic treasures that include a resolvable galaxy, a nearby planetary nebula, and one of the sky's most studied objects.

Despite the faintness of its stars, the figure of Pisces the Fish is easily traced. Look for a large V-shape of 4th- and 5th-magnitude stars, 30° on a side. At the west end is the Circlet, a group of five stars that more resembles a pentagon. Pisces is drawn as two fish joined at their tails, with the knot at Alpha (α) Piscium. Cetus the Whale is another autumn constellation associated with water. Finding a whale among these 4th-magnitude stars is difficult, but there are recognizable patterns to guide your way through the constellation. Perhaps the easiest to spot is what could be dubbed a "False Circlet," a scaled-up version of the true one in Pisces, 50° to the west. To the southwest lie four stars that form a large version of the handle of the Teapot in Sagittarius. The constellation's brightest star is 2nd-magnitude Diphda (Beta [β] Ceti), which appears yellowish to the naked eye.

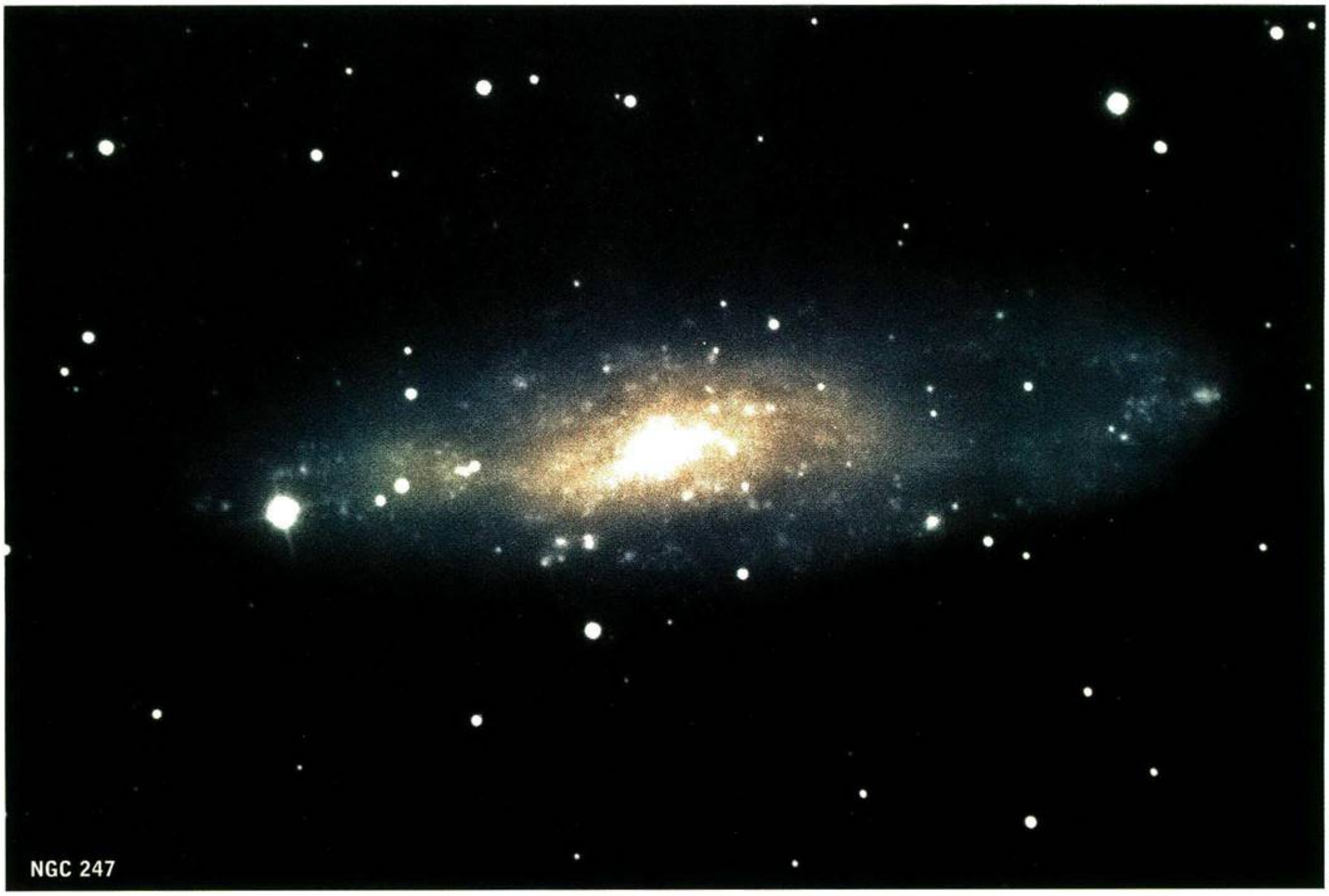
The autumn sky is filled with galaxies of modest brightness. One such galaxy, **NGC 157**, lies 4° east and just slightly north of the bright star Iota (ι) Ceti. A study aimed at detecting and cataloging HII regions turned up 88 in NGC 157. Allan Sandage's classic book *The Hubble Atlas of Galaxies* notes that "the first impression of this galaxy is that the entire surface is covered with luminous segments of spiral arms and interspersed dust lanes." A large backyard telescope begins to show this knotty spiral structure most prominently to the northwest and south of a nonstellar core. An 8-inch scope should show a small outer halo surrounding the bright nucleus.

Move southeast and form an equilateral triangle with the 5th-magnitude stars Psi^1 (ψ^1) and Psi^2 (ψ^2) Ceti to find the planetary nebula **NGC 246**. A 6-inch telescope under a dark sky reveals a large disk with several stars across its face, including an obvious central star. Through a 13-inch scope, a hollow center and a bright, thin rim on the northeast appear. A narrowband nebula filter dramatically improves the visibility of the patchy inner structure that makes this object so unusual. At 1,500 light-years, NGC 246 is relatively nearby. Its central star is one of the hottest known and one of a minority from which x-ray emission has been detected. Look for the little galaxy **NGC 255** less than a degree northeast of the planetary nebula.

Diving south, to a position 3° south-southeast of Beta Ceti, brings you to the bright galaxy **NGC 247**. This odd example is one of the five visually interesting spiral galaxies belonging to the Sculptor group of galaxies. The Sculptor group consists of a loose gathering of a couple dozen galaxies just outside the confines of the Local Group at an average distance of about 8 million light-years.

Although it emanates nearby, the light from NGC 247 is spread out over a large area and therefore is difficult to detect against a bright sky. The galaxy appears nearly 15' long with a 9th-

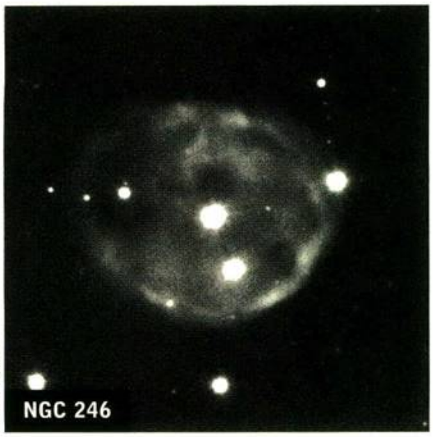
Artwork at left originally published in *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.


NGC 247

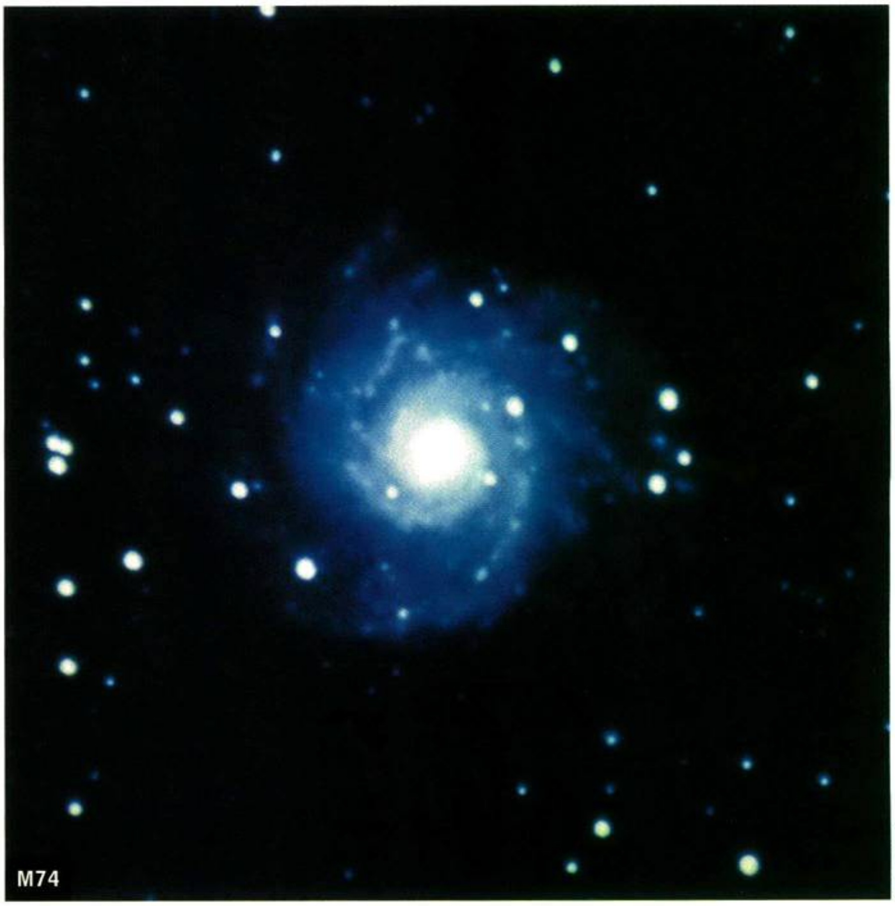
Kim Zussman

M77

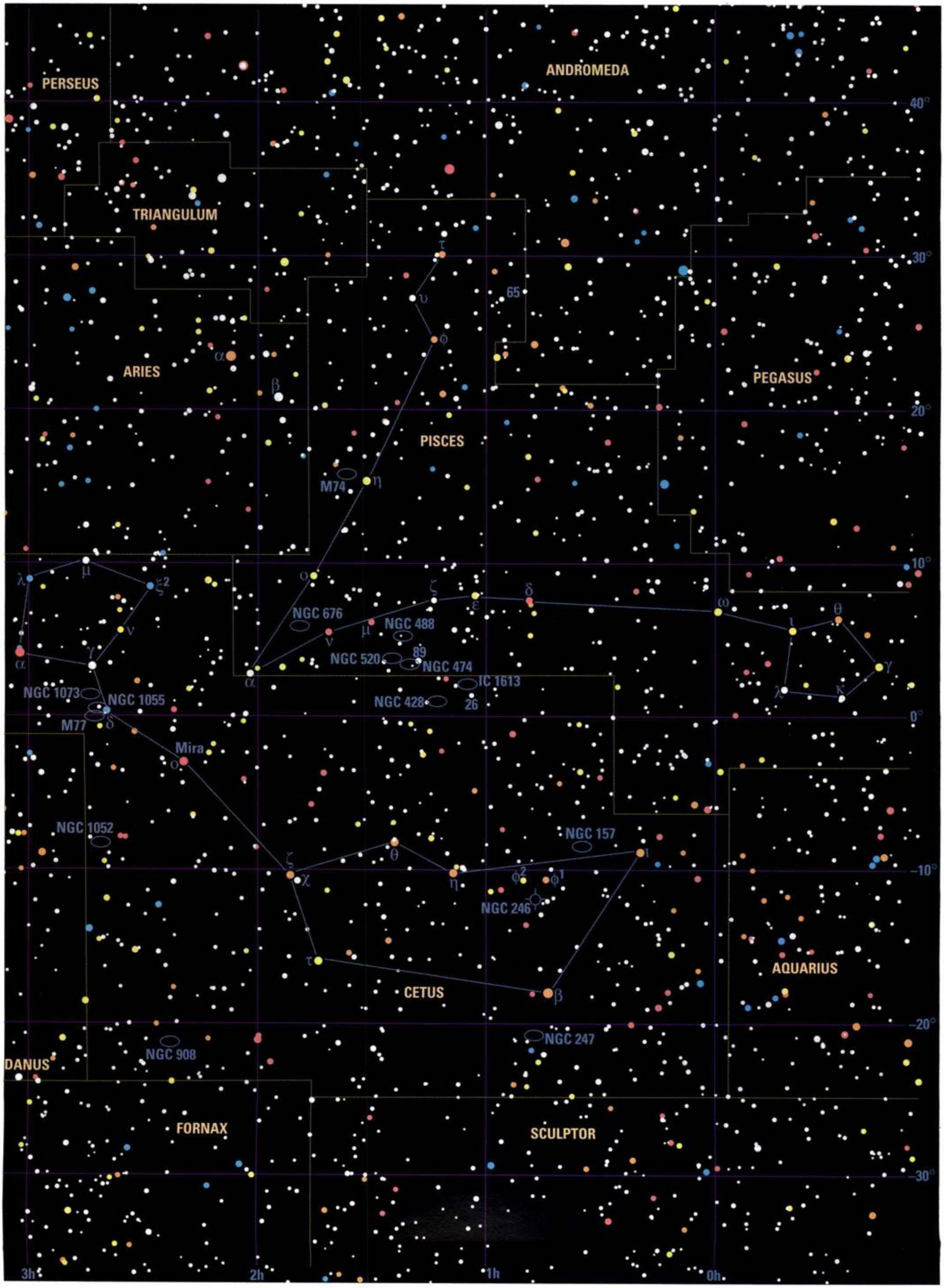
Jack Newton


NGC 246

Chuck Vaughn


M74

Patrick Martinez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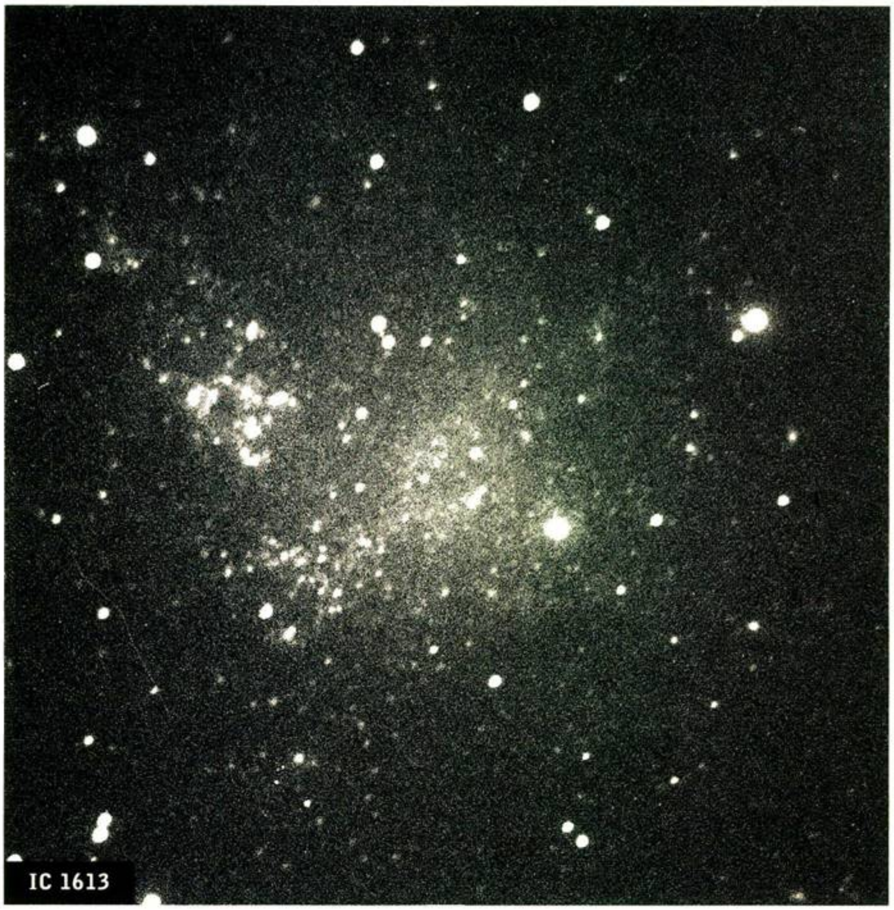
magnitude star shining in front of its southern end. It tapers from a point at this star to a rounded form on the north similar to the edge of the Andromeda Galaxy. At the center is a very broadly concentrated core.

Closer still is the sparse, irregular Local Group galaxy **IC 1613**, found about 1° southwest of the bright double star 26 Ceti, along the constellation's northern boundary. Modern measurements place IC 1613 just over 2 million light-years away. Its lack of obscuring material allows the light of much more distant galaxies to shine between its resolved stars. IC 1613 was thought to be a Local Group x-ray source until it was learned that the emission is associated with a galaxy cluster many times farther away.

I saw this galaxy in a 13-inch telescope as a faint, round, and uniform haze a quarter-degree across. It should be barely visible in an 8-inch instrument at a dark site. IC 1613 comes to life in a large scope. Viewing at 245x with a 20-inch reflector, the galaxy's central glow broke up into several dozen 17th-magnitude stars. Seeing the light of individual stars that has traveled for 2 million years is the type



Harvey Freed

Deep-Sky Objects in Pisces and Cetus

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
NGC 157	0h34.8m	–8°24'	10.4	4.0' by 2.4'	Gal	SAB(s)c
NGC 246	0h47.0m	–11°53'	10.9	225"	PN	
NGC 247	0h47.1m	–20°46'	9.2	19.0' by 5.5'	Gal	SAB(s)dm
65 Piscium	0h49.9m	27°43'	6.3, 6.3	4.6"	Dbl	
IC 1613	1h04.8m	2°07'	9.2	20.0' by 18.5'	Gal	IB(s)m
NGC 428	1h12.9m	0°59'	11.5	4.6' by 3.4'	Gal	SAB(s)dm
NGC 474	1h20.1m	3°25'	11.5	10.0' by 9.2'	Gal	SAB0 pec
NGC 488	1h21.8m	5°15'	10.3	5.5' by 4.0'	Gal	SA(r)b
NGC 520	1h24.6m	3°48'	11.4	4.6' by 1.9'	Gal	Pec
M74 (NGC 628)	1h36.7m	15°47'	9.4	11.0' by 11.0'	Gal	SA(s)c
NGC 676	1h49.0m	5°54'	9.6	4.6' by 1.7'	Gal	S0
Mira	2h19.3m	–2°59'	2.0–10.1	331.96d	Var	
NGC 908	2h23.1m	–21°14'	10.4	5.9' by 2.3'	Gal	SAB(s)c
NGC 1052	2h41.1m	–8°15'	10.5	2.5' by 2.0'	Gal	SA(r)0
NGC 1055	2h41.8m	0°26'	10.6	7.3' by 3.3'	Gal	Sb
M77 (NGC 1068)	2h42.7m	–0°01'	8.9	8.2' by 7.3'	Gal	SAB(rs)ab
NGC 1073	2h43.7m	1°23'	11	5.0' by 5.0'	Gal	SB(rs)c

Object: Designation in Messier, NGC, or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Hubble type for galaxies.

of observing highlight that keeps the most-veteran observers transfixed.

Exactly 2½° east of IC 1613 lies the galaxy **NGC 428**, a spiral that shows a bright, broadly concentrated oval disk and some mottling around its periphery. Look for its faint companion, **UGC 772**, 15' to the southeast. To its northeast, less than a degree east of 5th-magnitude 89 Piscium, is **NGC 474**, which is classified as an S0 galaxy, a lenticular, or lens-shaped, galaxy. Its outer halo shows signs of a weak gravitational interaction with **NGC 470**, only 5' to the west. Through the eyepiece, NGC 474 is bright but small, with an intensely concentrated center. An outer halo that is not visible in backyard instruments brings its cataloged size to five times the visible extent. NGC 470 is a fainter, larger companion to NGC 474. Look for a bright core and a faint ring on the outside edge of the halo.

Pan one degree to the east of NGC 474 to locate **NGC 520**, a peculiar pair of interacting galaxies cataloged as a single object. NGC 520 was originally thought to be one disturbed galaxy, like M82, but two distinct nuclei show up in high-resolution images. Even a small scope will show the peculiar form. Initially appearing similar to an edge-on galaxy, a closer look brings out a sharp, brighter northwest edge and pronounced absence of a surrounding halo. In larger instruments, a dark lane that divides the two galaxies becomes visible. Deep images reveal long, wispy streamers extending to the south and northeast ends. Perhaps these are visible in very large amateur telescopes. A degree and a half to the north lies NGC 488. This bright spiral has a 1' core surrounded by a large halo that is elongated north-south. Look for a line of four equally spaced stars to the south of the galaxy. NGC 488 is about 100 million light-years away. Farther east lies **NGC 676**, an ordinary Sa-type spiral galaxy with one unusual feature: a 9th-magnitude star placed squarely over the center. The lens-shaped galaxy appears about 3' by 1' and is elongated roughly north-south.

Use the bright stars Alpha and Beta Aretis as "pointers" to locate the gorgeous face-on spiral pattern of **M74** (NGC 628), just 1½° northeast of the bright star Eta (η) Piscium. At a distance of 24 million light-years, stellar associations and gas clouds in this galaxy stand out well. Working with an 8-inch telescope in the Arizona desert, A. J. Crayon saw the spiral structure as an uneven, mottled halo surrounding the bright core. My 13-inch scope shows two arms with difficulty. The half dozen stars superimposed on the galaxy's glow make it a more impressive sight.

It's a long journey northward to the Andromeda border to our next object, the double star **65 Piscium**. The two perfectly matched, white stars separated by just over 4" look like a pair of distant headlights. Use magnifications of 150x and above for the cleanest split. Those using large scopes under turbulent conditions can benefit by an off-axis aperture mask that cuts glare and increases contrast. Swinging way to the south, check the next galaxy in the southeastern corner of Cetus. **NGC 908** is a fine spiral galaxy that reveals more detail with increasing aperture. In an 8 inch it appears as an oval haze, elongated east-west. The core is quite a bit brighter, and ghostly hints of spiral structure appear at high magnifications. Through a 16-inch scope, an arm that radiates to the north of the core and turns abruptly to the west is quite prominent. A fainter arm that can be seen with more difficulty extends due east and ends near a 15th-magnitude star.

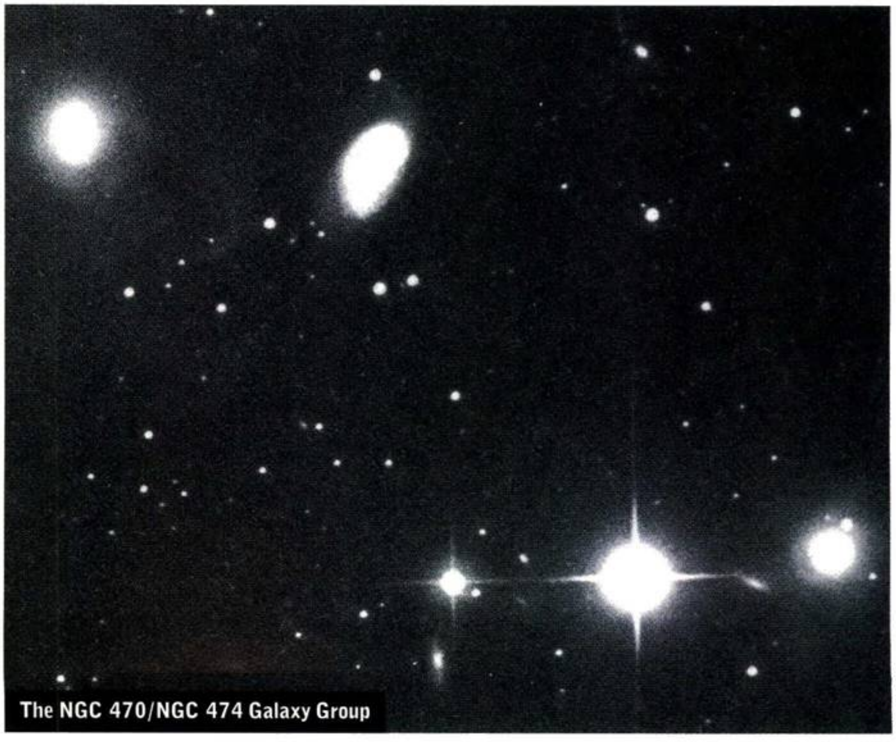
Nicknamed "The Wonderful," **Mira** (Omicron [o] Ceti) is the archetype for an important class of variable stars. So-called Mira-type variables have long periods and large-amplitude variations in brightness. The prototype varies irregularly over 332 days between 2nd and 10th magnitude. In February 1997, Mira reached nearly 2nd magnitude, but at its next maximum in the beginning of 1998, disappointed observers by attaining only 4th magnitude. This autumn is a great time to monitor its climbing

NGC 1055

Martin C. Germano

NGC 1073

James R. Foster



The NGC 470/NGC 474 Galaxy Group

Martin C. Germano

The Fish and the Whale

Anaximander says that men were
first produced in fishes,
and when they were grown up
and able to help themselves were thrown up,
and so lived upon the land.
Plutarch's Lives; *Symposiacs, Book VIII, Question VIII.*
— Plutarch (46?–120?)

Considered the last of twelve zodiacal constellations, Pisces the Fish was known as "the Tails" to the Babylonians. In the sky, Pisces is depicted as two fish tied together by their tails, one swimming in the opposite direction of the other.

Though the constellation's origins can be traced back to Babylonian times, its history is a bit sketchy. The most notable story takes place soon after the gods of Olympus defeated the Titans. Gaia (Mother Earth) coupled with Tartarus (a section of the Underworld reserved for the most nefarious). From this union came Typhon, a monster so tall he was able to touch the stars. Typhon had 100 fingers, each with its own dragon head, and his eyes spouted fire.

Gaia sent Typhon to attack the gods. Aphrodite and her son Eros hid in the reeds along the bank of the Euphrates River. But the wind rustled and Aphrodite feared they would be discovered. She called to the water nymphs for help and two fish were sent to guide the goddess and her son to safety. Aphrodite placed the fish in the sky as tribute for their deed.

Cetus the Whale is the infamous sea monster that battled Perseus for Andromeda. Andromeda was a princess whose mother (Cassiopeia) was arrogant and whose father (Cepheus) was weak. One day, Cassiopeia boasted of her beauty and insulted the Nereids (sea nymphs) by claiming she was more beautiful than they. For the offense, Poseidon sent a terrible monster to ravage the coastal kingdom.

The Oracle of Ammon told Cepheus that Cetus would be appeased if Andromeda was sacrificed to him. Cepheus didn't protect his daughter; instead, he had her chained to the rocky ocean cliffs. Fortunately, before Cetus could eat Andromeda, Perseus came along and freed her. The hero used Medusa's recently severed head to turn Cetus to stone. — *Andrea Gianopoulos*

brightness, as it is slated to peak in early November. Use the giant "V" of Pisces to locate Mira; the asterism points right to it.

At the eastern edge of Cetus lies a nice trio of galaxies highlighted by **NGC 1052**. Studies of this elliptical galaxy have shown that the core contains a faint disk of ionized gas. Astronomers believe this gas originated from an encounter with a nearby spiral such as **NGC 1042**, though no signs of interaction are apparent. Through the telescope, NGC 1052 is a bright, oval haze, elongated in p.a. 135° and exhibiting a remarkably bright, starlike nucleus. A quarter degree southwest, NGC 1042 is considerably fainter and larger. My 20-inch scope brought out dim hints of spiral structure. **NGC 1035** lies 23' northeast of NGC 1042. It appears 3' by 1' with a sharp, slightly brighter center. A medium-power view that contains all three contrasting galaxies is the most pleasing.

Less than a degree east-southeast of 4th-magnitude Delta (δ) Ceti lies the magnificent galaxy **M77** (NGC 1068). The original Seyfert galaxy, it is among the most studied objects of its type in the heavens. At a distance of 47 million light-years, it has one of the closest and brightest active galactic nuclei. It appears that matter is funneling into this region due to gravitational effects. Radio observations suggest a central black hole of 20 million solar masses. The star formation regions are the most luminous known within 100 million light-years. Finally, the inner disk of M77 is notable for its high surface brightness. This last point is of special interest to visual observers. M77 is catalogued at 7' by 6', but it is the inner 2' that steals the show. Use your highest magnifications to get the most out of the structure. An 8-inch scope will show the blazing core to be nonstellar and surrounded by a bright disk that may reveal some mottling. The oval disk is elongated in p.a. 45°. A 16-inch telescope will bring out tight spiral structure surrounding this bright disk and extending to 2'. The brightest spiral arm lies southeast of the luminous core. Like planetary observing, viewing the most detail in M77 often requires waiting for periods of the best seeing.

A half degree north-northwest of M77 you'll find **NGC 1055**. It appears in a small scope as a spindle, 3' long, and aligned nearly east-west. To the north, two stars, 7th and 8th magnitude, fit into a high-power field. A moderate-sized telescope is needed to see a dust lane running along the north edge. I noticed a similarity between this galaxy and the Sombrero Galaxy, M104.

Scan one degree north-northeast of M77 to find the faint barred spiral, **NGC 1073**. Its brightest feature is the bar, which is 2' by 1' and elongated in p.a. 60°. My 13-inch scope began to show signs of spiral arms. These became obvious through a 20 inch. I traced one arm from the northeast end of the bar curling around the core to the north and west, and noticed a more elusive southern arm. There are no less than three quasars floating near the outer arms of NGC 1073. Renegade astronomer Halton Arp noted that the probability of finding this many high-redshift quasars so close to a low-redshift galaxy is one in 50,000. He has argued that the high redshift of quasars is due to ejection events from the galaxy itself rather than cosmological expansion. ■

Tom Polakis is an aerospace engineer who lives in Tempe, Arizona. He has observed and photographed deep-sky objects for many years.

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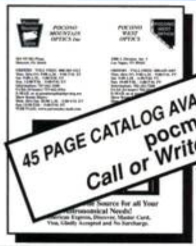

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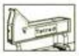

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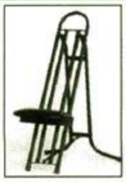

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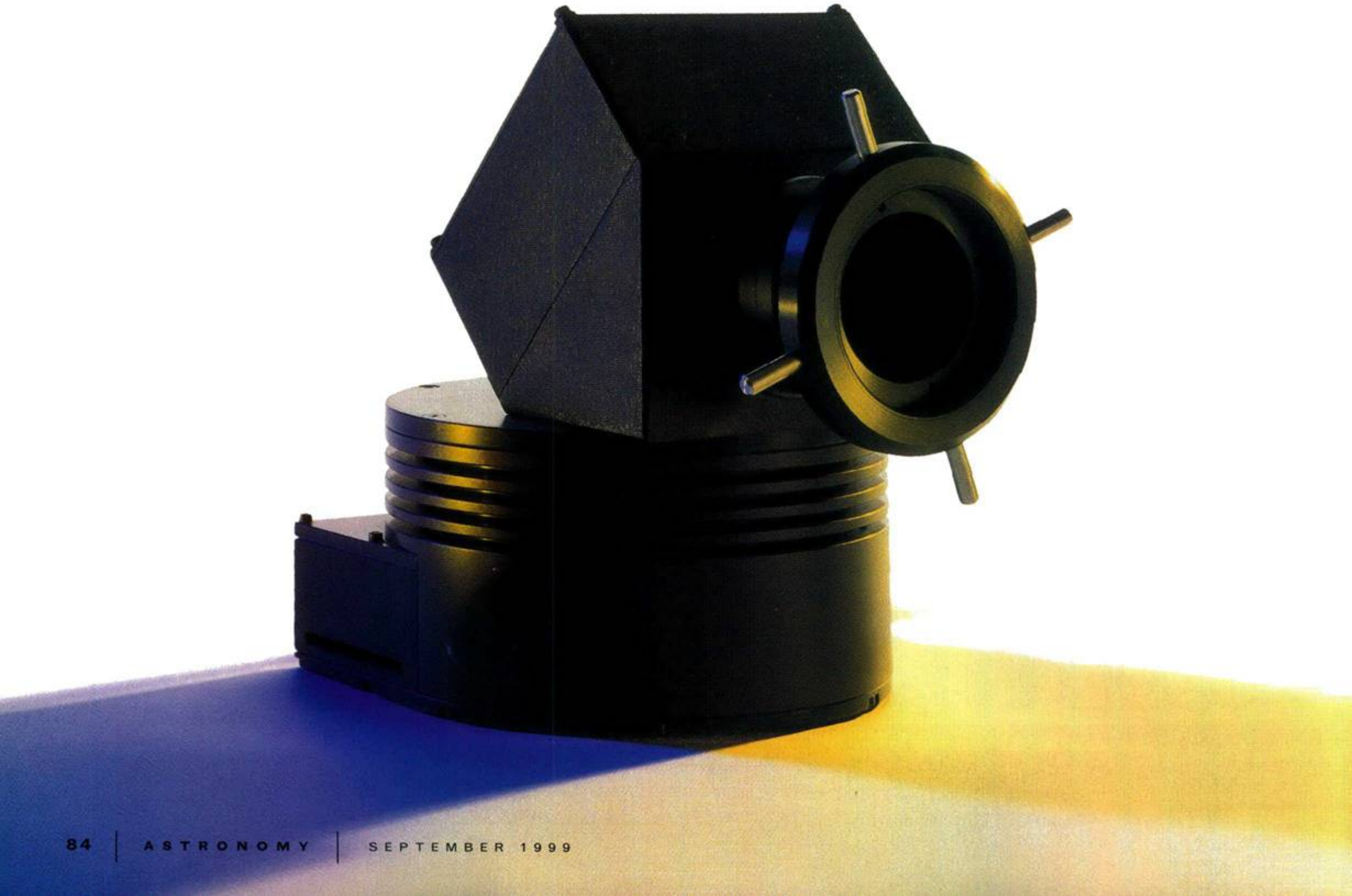
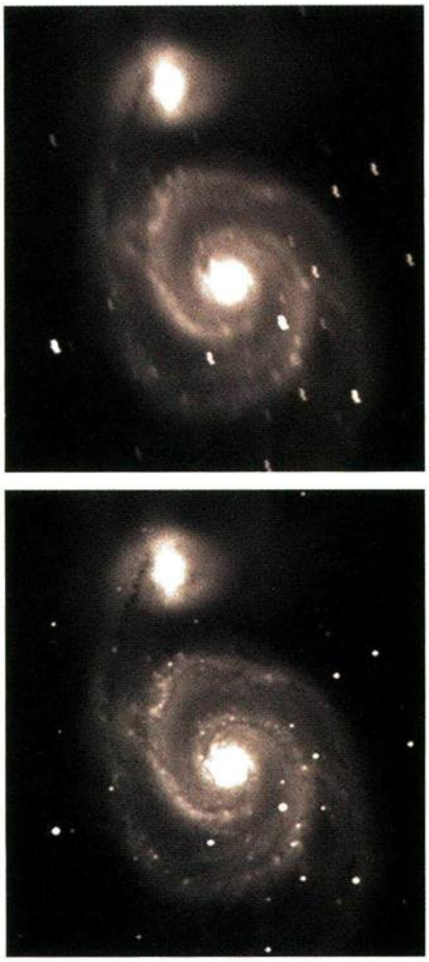
Adaptive Optics Meet CCDs

The Santa Barbara Instrument Group offers an imaging system that self-adjusts for sky conditions and a mount's tracking errors.

by Gregory Terrance



ALL EARTH-BOUND ASTRONOMERS, from backyard observers to the professionals at Mauna Kea Observatory, have to view the sky through our planet's atmosphere. Clouds aren't the only concern. Even a clear night poses challenges. Recently, the Santa Barbara Instrument Group (SBIG) introduced an adaptive optics package that helps sharpen blurry images. The AO-7 hardware works in harmony with two of SBIG's CCD cameras, the model ST-7 and ST-8. Its two main components include a high-speed tip-tilt mirror system for "atmospheric corrections" and a new image enhancement software package called CCDSharp.



Top: The Whirlpool Galaxy (M51) taken with a portable mount purposefully offset from true north. The image is blurred due to improper tracking by the telescope's mount.
Bottom: The identical setup and exposure but auto-guided by the AO-7. Gregory Terrance

Any astro-imager can relate the importance of adaptive optics to the hobbyist. The atmospheric plague known as "seeing" usually goes unnoticed by naked-eye observers. Yet it is critical for telescopic viewing and astro-imaging. Seeing refers to the steadiness of the atmosphere, and it can have a dramatic impact on how detailed a celestial object appears through an eyepiece or on a CCD chip. Steady or sharp seeing indicates a calm atmosphere in which photons pass through unscathed yielding a crisp image. Unsteady or poor seeing gives the opposite result and is typical for major portions of each night.

Local conditions and upper atmospheric turbulence cause a star's image to move and become unfocused during a CCD exposure. As starlight moves around on the detector's surface, it creates a blurry image making the star appear larger than it would under steady conditions. This effect leads to an overall reduction in sharpness and resolution.

Adaptive optics were designed to combat these poor seeing effects by taking the "twinkle" out of stars. The techniques (there are many different types) were originally developed by the U.S. military for tank and aircraft targeting systems. Professional astronomers have used them for years to significantly improve the resolution of earthbound telescopes.

Tip-Tilt, High-Speed Guiding

SBIG uses a high-speed adjustable mirror to suppress atmospheric turbulence, wind-induced vibrations, and periodic drive errors. The unit employs the second guiding CCD of the ST-7 or ST-8 camera to detect a star's movement. The star's position is read and the tip-tilt mirror moves rapidly to hold the star on a specified pixel during exposure. Naturally, the tip-tilt mirror also keeps the entire CCD image steady because all the incoming light is reflected. SBIG claims the mirror moves and settles to within 20 percent of the commanded position in a mere 10 milliseconds — much faster and more responsive than any telescope mount.

This response means the AO-7 is capable of moving plus or minus 50 pixels when used with the SBIG ST-7 camera which amounts to two arcminutes of correction with an 8-inch f/10 telescope. The AO-7 should also be able to accommodate the periodic error of most mounts without the need to correct the right ascension drive axis directly. If further corrections are required, the adaptive optics system will move the mount, provided it has been properly calibrated. I was delighted to find a portable mount, with less than perfect polar alignment, could produce good images using the adaptive optics as an auto-guider.

The Nuts and Bolts

The AO-7 adaptive optics unit is only compatible with an SBIG ST-7 or ST-8 CCD camera (See "CCD Cameras Get Savvy," April 1998, for a review of the ST-7 and ST-8) and is designed to work with SBIG's most recent color filter wheel, the CFW-8. The older CFW-6 is not supported.

The components of SBIG's adaptive optics unit include a mirror housing, mounting bracket, and Schmidt-Cassegrain adapter. The additional 21 ounces of weight should not significantly affect telescope counterweight requirements. The Schmidt-Cassegrain adapter is designed to thread directly onto the back of most catadioptric telescopes and can be removed for use with reflectors or refractors. The housing enclosure holds the electronics, motors, and tip-tilt mirror. Unseen is a needle bearing and a set of magnetically operated voice coils that allow the mirror to make corrections — up to 40 times per second.

Once the adaptive optics package is attached, light enters the digital camera at a 90° angle, giving the

Resting atop SBIG's ST-7 camera, the AO-7 offers astro-imagers an avenue to sharper images. Photograph by Jim Forbes

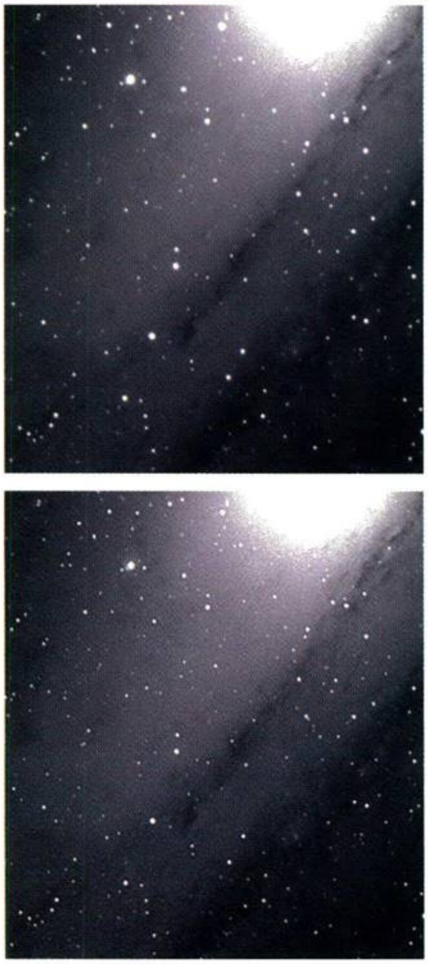
AO-7 the appearance of a telescope's star diagonal. However, looks can be deceiving. The AO-7's movable tip-tilt mirror quickly distinguishes it from such devices. Because the adaptive optics add another reflecting surface, all images coming from the system are inverted and easily corrected during image processing.

Getting Started

SBIG's adaptive optics module requires high-speed communication between the CCD camera and the AO-7. A new ROM (Read Only Memory) must be installed for this link. The ROM is provided with the AO-7 package and installs in minutes. The adaptive optics module itself attaches directly to the front of an ST-7 or ST-8 camera once the standard nosepiece has been removed. All necessary tools are included and installation is easy. Even the most cautious user will be able to perform the process in less than 20 minutes.

The AO-7 has an additional 3.5 inches of telescope "in-travel," which may not allow some telescopes to reach focus. For example, a 10-inch f/6 and 16-inch f/5 Newtonian that had no problem imaging with the ST-7 would not reach focus with the adaptive optics unit attached. Fortunately most refractors and all Schmidt-Cassegrain telescopes will not suffer from this problem. I used the AO-7 with two refractors (6-inch f/7 and 5-inch f/8) and an 8-inch f/10 SCT. Each telescope was able to reach focus, with room to spare.

There were no surprises using the AO-7. Any astroimager familiar with an SBIG CCD should be able to make the jump to the adaptive optics system with nothing more than a glance at the owner's manual. In fact, until its adaptive optics were put to use, the AO-7 was invisible to standard CCD imaging procedures (finding, focusing, and exposing).


Top: A portion of the Andromeda Galaxy (M31) taken with a 10" f/6 reflector and auto-guided with the ST-7.
Bottom: The same image parameters but processed by CCDSharp. Gregory Terrance

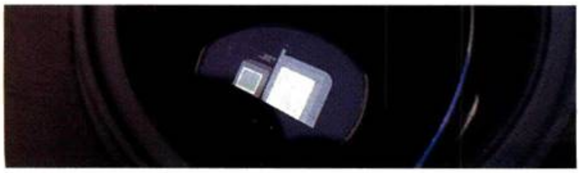
Once the camera is focused, the adaptive optics unit has to be calibrated. This allows the software to determine how much the mirror will move for any given command. Fortunately, this calibration is much faster and more straightforward than calibrating a telescope's bulky mount. Since the mass of the AO-7's mirror is quite small (compared to that of a telescope's mount), the AO-7 can make its calibration adjustments very quickly.

The procedure takes only seconds to complete, and successful calibrations are generally achieved in one attempt. The system is definitely "user friendly" and avoids the steep learning curves associated with some high-tech devices. I also thought it was easy to set up and use the AO-7, more so than any autoguider I've encountered, including SBIG's ST-4.

Self-guiding with the AO-7 has a number of advantages over mount self-guiding. Adaptive optics functions are not declination dependent. They are also unaffected by camera rotation, which means the calibration procedure only has to be performed once per imaging session. Even if the camera is moved to frame an object or to a significantly different declination, the adaptive optics maintain their calibration.

Recommendations

The AO-7's mirror has a limited amount of movement, so mounts with significant right ascension or declination drift will eventually run out of mirror travel room. These systems will have better results if the telescope's mount is also calibrated to allow the adaptive optics module to nudge the mount back to a point

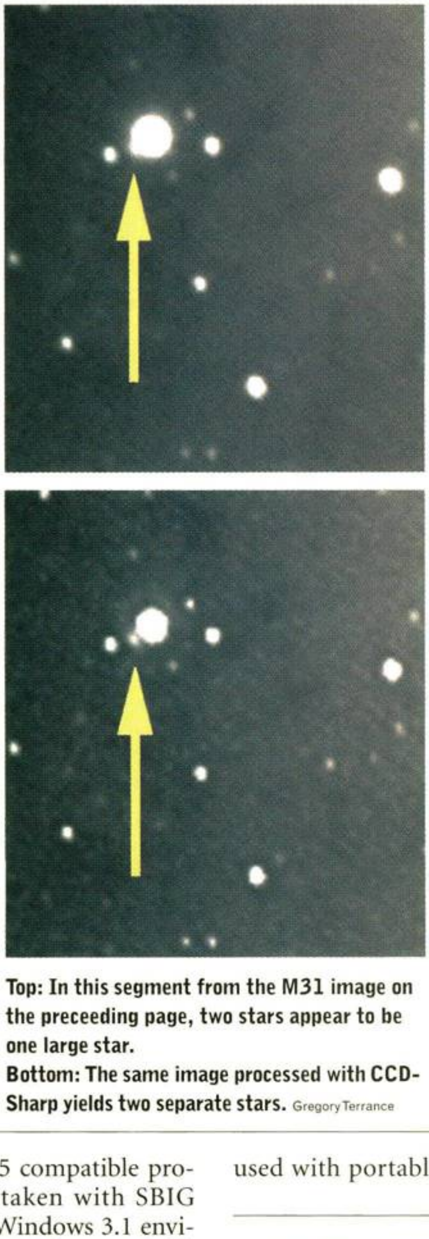

The AO-7 adaptive optics system uses a tip-tilt mirror to adjust for sky conditions and mount-tracking errors. The mirror moves and settles to within 20 percent of the command position in a mere 10 milliseconds. This keeps the object centered on the camera's chip, yielding a sharper image. *Astronomy:* Jim Forbes

where the AO-7 can take over. This enables the system to track for longer exposures.

All telescopes and their mounts are not created equal. A scope's focal length and the mount's right ascension drive and polar alignment are all factors to consider when using the AO-7. Because the effects of seeing become more noticeable with longer focal lengths, telescopes with focal lengths of 2000mm or more will be able to take advantage of the AO-7's atmospheric corrections. This is due to the nature of the optics involved and the 9-micron pixel used by the Kodak chips. Under most conditions, short focal length systems will not be able to resolve the AO-7's atmospheric improvements to the image.

Having said that, a short focal length system can also benefit from the adaptive optics module. While true adaptive optics effects will not be evident, guiding errors, even under less than ideal conditions, can nearly be completely eliminated with the AO-7. This is a blessing to astro-imagers who travel to remote sites. Compared to permanent installations, portable mounts often suffer from polar alignment errors, and in some cases, right ascension drive errors.

In the final analysis, telescopes below 2000mm that are held by a high-quality, well polar aligned mount will benefit the least from the AO-7. Long focal length systems will benefit the most.



Top: In this segment from the M31 image on the preceeding page, two stars appear to be one large star.

Bottom: The same image processed with CCD-Sharp yields two separate stars. Gregory Terrance

Software

CCDSharp is a 32-bit, Windows 95 compatible program designed to sharpen images taken with SBIG cameras. It will not run in a DOS or Windows 3.1 environment and only processes native SBIG formats (with the exception of ST-4 files). The program uses a Lucy-Richardson algorithm to process the images. The technique is very calculation intensive. It takes about 20 minutes for an ST-7 frame to be processed on a 133 MHz Pentium machine. A 300 MHz Pentium cuts this time in half to roughly 10 minutes per frame.

I liked CCDSharp and the effects it produced on deep-sky images. In particular, star images and the resolution of nebulosity showed noticeable improvements. The program has the ability to make these improvements without leaving objectionable processing artifacts that often give images an overprocessed or unnatural look. CCDSharp did not significantly increase image noise levels unless the processing was pushed to the limit. In some cases, (see images at left) stars that had been indistinguishable from each other before processing became apparent afterward. Even at a high level of zoom, star images remained fairly natural and noise levels were not objectionable.

Santa Barbara Instrument Group's AO-7 adaptive optics package is yet another example of how high-tech devices have entered into amateur observatories. With this system, SBIG delivers a one-two punch to the primary contributors of mediocre CCD images: poor guiding and unsteady skies. While the AO-7 module improves the chances of getting good, raw images, CCDSharp allows you to extract the most from those images. The AO-7 package definitely adds a new dimension to imaging with SBIG cameras, especially when used with portable mounts.

Gregory Terrance is an astro-imager and frequent contributor to Astronomy. *Visit his website at www.frontiernet.net/~gregoryt.*

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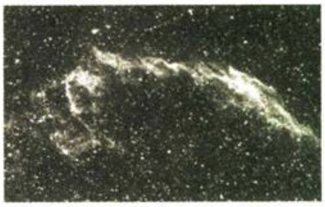

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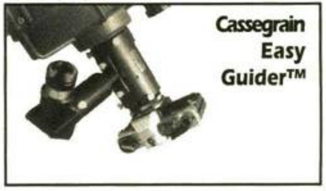

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Meteorite Value, Planetary Collisions, Tipsy Uranus

How much would you pay for this 32-gram meteorite found in Antarctica? NASA

Q: I was tempted to purchase a 28-ounce meterorite for $500, but didn't because I wasn't sure of its value. How much per ounce should one expect to pay for a meteorite? — *Bill Logan, Scottsdale, Arizona*

A: In order to answer, I must first make a slight correction to your question. Meteorites are sold by the gram (1 oz = 28.349 g and 1 lb. = 454 g). So a 28-ounce iron is 28 x 28.349, which equals 794 grams. That's about $0.63 per gram, a high price. The reputable catalog *Mitterling Meteorites* lists a Canyon Diablo iron weighing 1,398 grams for $595 and another one weighing 487 grams for $122.

Gift shop prices tend to be high, but so do prices elsewhere. Cost also depends on the kind of meteorite. There are three basic types: stones, irons, and stoney irons. Stones consist of ordinary chondrites, which sell for between 3 and $10 per gram. Carbonaceous chondrites fetch about $8 per gram and up. The rare achondrites begin at 10 to $12 per gram for a Millbillillie (a portion of Vesta) but can go up to $700 per gram for a Zagami (Mars), $2,500 per gram for a DAG 476 (Mars), and $25,000 per gram for a DAG 400 (the moon).

Two types of people tend to buy meteorites: those who wants to own a meteorite or two and collectors.

If you are the first type, I would recommend one or more of the following:

- A Gibeon or Canyon Diablo iron.
- An ordinary chondrite selling for about $1.50 per gram.
- A small slice of Allende, a CV3 carbonaceous chondrite, which runs about 7 to $10 per gram.
- If you want an achondrite, purchase a piece of Millbillillie.
- And if you get this far, you might want to have a Pallasite, Esquel.

If you buy from a dealer, be cautious. Dealers can be very pushy. A good place to go first is the Meteorite Exchange website at www.meteorite.com. — *Jim Phillips is a meteorite collector with specimens on display at South Carolina State Museum in Columbia*

Q: If globular clusters orbit the galactic cluster, how can they maintain their shape and remain dust-free? — *Doug Herbst, Staten Island, New York*

A: Gravitational capture of an object (in this case a dust particle) is usually a complicated process that depends on the number of bodies involved, their masses, and their relative velocities. The stars in a globular cluster are too small, spaced too far apart, and moving too rapidly relative to the galaxy to capture a significant amount of dust during a plane passage.

As it turns out, the shape of a globular cluster is modified when it passes through the galactic disk. When it formed, a typical globular cluster probably had more stars farther from its core than it would today. However, gravitational tides from the galactic disk would strip those stars after repeated passages, leaving a smaller object. What we see now, after many orbits through the galactic disk, is a smaller, more tightly bound globular cluster. Any star that could have been stripped by the tides from the galaxy is

Gravity keeps the stars in M3 bound together in a tight cluster. Philippe Durville

long gone, torn off many orbits ago. — *Phil Plait, The Bad Astronomy Home Page, http://www.badastronomy.com*

Q: Why, in a universe with an infinite number of planes, do orbiting objects stay within one plane? Why are there no planets with orbits perpendicular to Earth's? — *Brandon Van Hoff, Bremerton, Washington*

A: The current leading idea about how planets, galaxies, and stars evolved says that all the structures in our known universe formed from swirling gases created after the Big Bang. The gases have a physical property called angular momentum, which in simple terms is the direction or rotational axis of the forming system. In the absence of external forces, angular momentum is always conserved. This means that as the gases cooled and began to coalesce, the solid bodies that eventually formed maintained the same angular momentum as the original gases.

This same principle of physics also leads to the relatively fast orbital motions of planets about a central body. As more mass moves to the central body — in our case, the sun — the system has to speed its rotation to hold the angular momentum constant. It's the same physics that causes figure skaters to spin faster as they pull in their arms. There is no reason why a planet couldn't orbit about its central body in any plane. The issue is the mechanics of how it would get there. Many comets are in highly inclined orbits about the sun, and the Ulysses spacecraft, for example, is in a near polar orbit around the sun. — *Robert Mitchell, program manager, NASA's Cassini mission*

Q: What is an arcminute and an arcsecond? — *Teri Nelson, Richmond, Virginia*

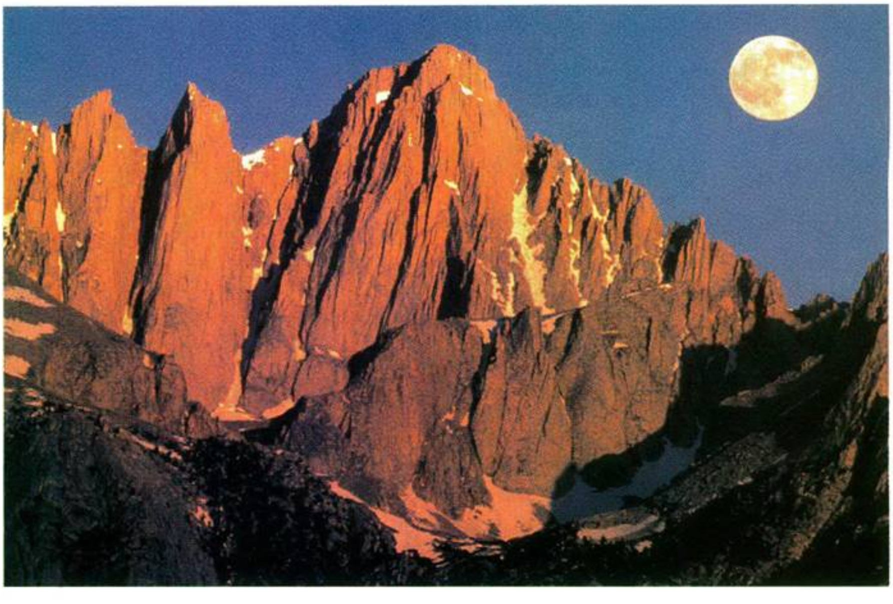
A: An arcsecond is a unit of measurement spanning $\frac{1}{3,600}$ of a degree and is expressed with the same symbol used to specify inches ("). Astronomers use arcseconds to describe the diameter of an object or the distance between objects when observed from Earth. (The apparent diameter of an object changes depending on the observer's proximity to it.) Sixty arcseconds make up one arcminute, a unit of measurement described with the same symbol used to express feet ('). To give you an idea of how big an arcminute is, take a look at the moon the next time it's full. A full disk measures about 30' across. Most of the planets measure between 5" and 40" wide. — *Tracy Staedter, associate editor*

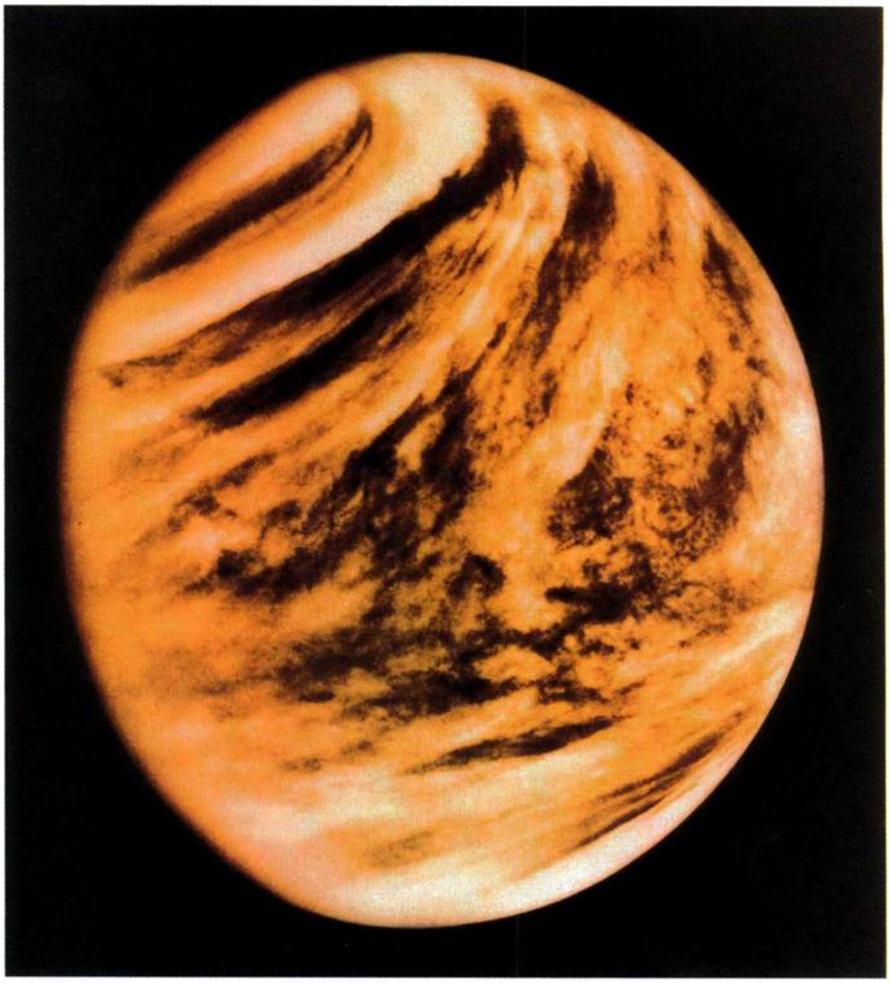
Q: Is it possible that because their orbits cross paths, Pluto and Neptune will eventually collide? If so, will the collision have an effect on the rest of the solar system? — *David Ceal, Longview, Texas*

A: For about 20 years of Pluto's 248-year orbit, the planet is closer to the sun than Neptune. But not to worry; the two planets will never collide. Pluto's orbital period is exactly 1.5 times that of Neptune. So every time Pluto goes around the sun twice, Neptune goes around thrice. This ensures that the two will never meet.

No one knows for sure how the orbits of Pluto and Neptune came to be arranged this way, but orbital studies have shown that if this weren't the case, Neptune's gravity would either

Astronomers measure the apparent diameter of most sky objects in arcminutes ('). The moon is 30' across. Jim Baumgardt





If you kept adding gas to the atmosphere of a world such as Venus, it would eventually resemble a jovian planet. NASA

eject Pluto from the region or the two would collide.

Theorists Martin Duncan and Jack Lissauer have recently discovered that when the sun expands into a red giant and losses a significant portion of its mass, the Pluto-Neptune resonance lock is likely to be lost. At that time, perhaps five billion years from now, Neptune will likely eject — or devour — Pluto. — *S. Alan Stern, Southwest Research Institute*

Q: Venus has a significantly denser atmosphere than Earth. Is there a maximum atmospheric carrying mass of a terrestrial planet? If so, what determines it? How close are Venus, Earth, and Mars to their maximum capacities? — *Bob Barauskas, Philadelphia, Pennsylvania*

A: In general, the thickness of a terrestrial planet's atmosphere is determined by the balance of sources and sinks (or loss processes). On Mars, with its puny gravitational field, the loss processes have won out and there is very little atmosphere. Earth's atmosphere is much thinner than Venus's because chemical reactions that make carbonate rocks constantly remove carbon dioxide (CO_2) from the atmosphere. These reactions require the presence of water. If Venus still had an ocean — as it probably did once — then the amount of CO_2 in its atmosphere would be much less. So under some circumstances there are natural limits on the atmospheric abundances of certain gases — those that can react with surface rocks or condense as liquids on the surface.

However, there are no such limits for a nonreactive gas such as nitrogen. As far as I know, there are no theoretical limits on the gas-carrying capacity of a terrestrial planet. If you just kept adding gases, a terrestrial planet would begin to resemble a jovian planet. There isn't any convenient dividing line between the two. In fact, Jupiter and Saturn may have objects with the approximate size and composition of Earth residing at their cores. Our solar system happens to be neatly divided up into planets that fit one category or the other, but judging from recent discoveries, there is a lot of diversity among planetary systems and these categories may have to be refined. — *David Grinspoon, University of Colorado, Boulder*

Q: What will happen to Earth as the sun grows older? — *Anne Alonzo, Garland, TX*

A: In a word: disaster.

Over the last 3 billion years, the sun has been aging and getting hotter. Earth compensates for the extra heat by regulating the amount of CO_2 in its atmosphere. An increase in CO_2 helps warm the planet; a descrease helps cool it off. This regulation has been occurring over geological time and scientists think it is the main reason that Earth has maintained a fairly constant — and habitable — temperature over the last 4 billion years, despite radical changes in the sun, the composition of Earth, the placement and extent of oceans, and other changes.

The CO_2 cycle works like this:

CO_2 and water in the atmosphere combine and form a weak acid. Over geological time, this acid corrodes rocks made of magnesium, calcium, and silicate. This reaction turns the rocks into SiO_2 and releases the calcium and magnesium as ions in solution. The CO_2 ends up as bicarbonate in solution (CO_3).

The calcium, magnesium, and CO_3 then collect in the oceans and build up. In the oceans they reach saturation levels and begin to precipitate as calcite, which is calcium carbonate.

Clever, ocean-dwelling life-forms have figured out how to convert the saturated calcium carbonate into body parts such as shells, pearls, bony structures, and coral. When they die, the animals' parts end up on the ocean floor as carbonate.

Through plate tectonics, oceanic plates recycle the sediments by subducting them into Earth's interior. At great depths inside Earth, the sediments become heated and turned to gas, which comes up in volcanoes associated with subduction zones. The eruption of Mount St. Helens is a recent example of this outgassing. The CO_2 gases that came out of it were literally recycled CO_2 that started the cycle back at the beginning again.

How does this process help act as a thermostat? The rate of CO_2 reaction to form carbonate is strongly dependent on the temperature. If the temperature goes up, the rate of reaction goes up too, sucking CO_2 from the atmosphere very fast. The reduced CO_2 level then helps cool the atmosphere. If the temperature drops, the rate of reaction slows. The amount of CO_2 increases, and the temperature rises. This positive feedback will ensure that the planet's temperature will stay in a range where liquid water can exist, keeping Earth habitable.

However, this thermostat will only work if the level of CO_2 has some room to fluctuate above and below the optimum level. If the sun grew extremely bright, the thermostat would push the CO_2 level all the way down to try to cool off the planet. But it can only go so far. At some point, the thermostatic control will fail.

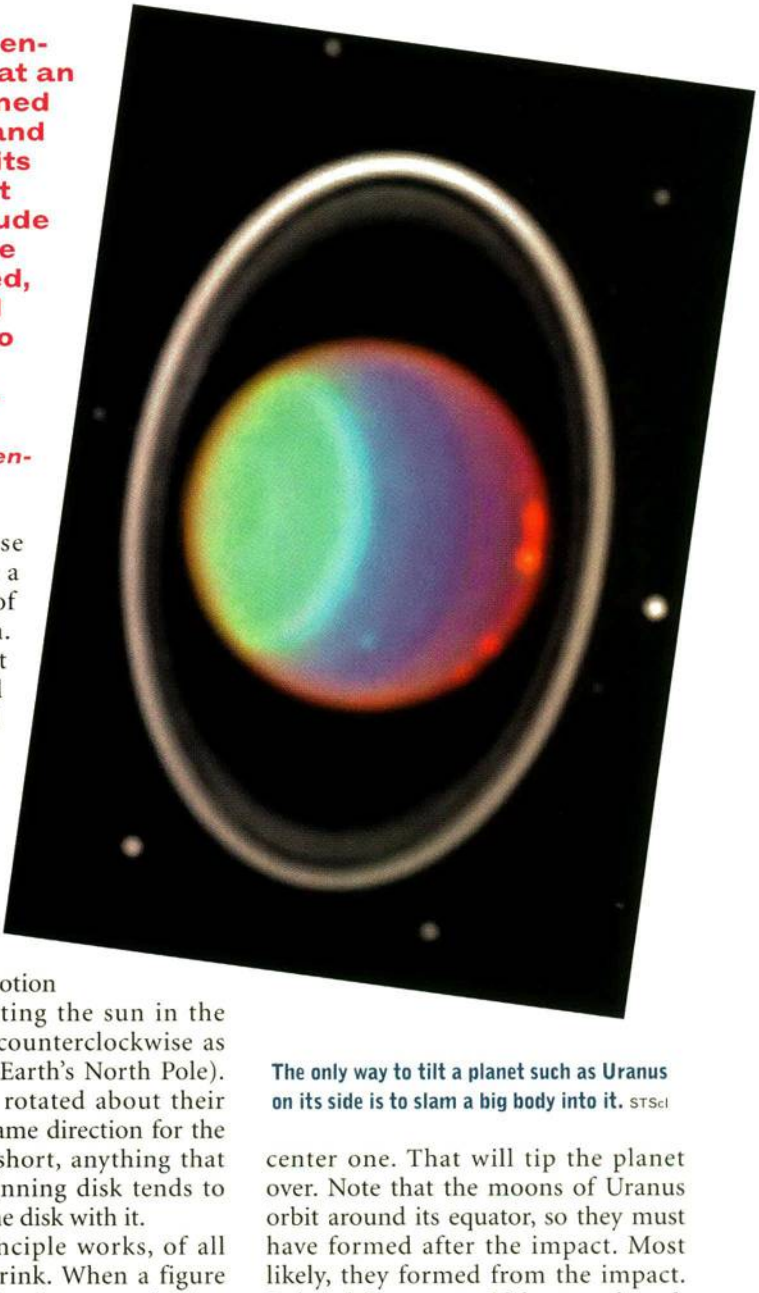
As the sun ages and grows hotter, three disasters are likely.

Disaster 1: Eventually the level of CO_2 will fall to values so low that plants can no longer take up CO_2. Depending on the details, this could happen 90 to 200 million years from now. No plants means no animals. Bacteria might still do fine.

Disaster 2: The sun gets even brighter and the CO_2 levels drop to zero, and still the temperature is too warm. At this point the planet loses its stability (there is no longer any feedback mechanism), and Earth is destined to enter a runaway Venus-like condition as the sun continues to get brighter. Roughly speaking, this would occur when the sun gets about 10 percent brighter than it is today; about 1 billion years from now. Earth is no longer habitable.

Disaster 3: The sun becomes a monstrous red giant. Earth is either inside the solar atmosphere or just outside of it. In either case, I would expect that the surface temperature of Earth would exceed the vaporization temperature of iron, in other words, Earth is not long for this world. — *Christopher P. McKay, NASA Ames Research Center*

Q: Why do scientists think that an object slammed into Uranus and tipped it on its side? Why not simply conclude that when the planet formed, its gases and dust began to spin in the tipped direction? — *Jesse Alexander, Greenville, Ohio*



The only way to tilt a planet such as Uranus on its side is to slam a big body into it. STScI

A: Scientists base their thinking on a standard model of planet formation. It maintains that the planets and the sun formed from a roughly spherical cloud that cooled and condensed into a flat spinning disk. When the planets formed, they maintained the motion of the disk, orbiting the sun in the same direction (counterclockwise as seen from above Earth's North Pole). The planets also rotated about their own axes in the same direction for the same reason. In short, anything that forms from a spinning disk tends to keep the spin of the disk with it.

The same principle works, of all places, in an ice rink. When a figure skater begins a spin, she starts with her arms out, spinning slowly. As she draws her arms in, her rotation rate increases dramatically. The amount of energy locked up in her spinning is the same, but with her arms close in it's easier to spin, so she spins faster. That's what happens when planets form from a spinning disk; they not only keep the direction of spin, but they actually amplify it, spinning faster than the disk did. And at no time would the skater's arms begin spinning in a different direction than her body.

When the planets formed, they probably all had vertical axes (with respect to their orbital plane, the plane of the original disk). The only way to tilt a planet is to slam a large body into it, either in a grazing impact or an off-center one. That will tip the planet over. Note that the moons of Uranus orbit around its equator, so they must have formed after the impact. Most likely, they formed from the impact. Debris left over would have coalesced, forming the moons.

Incidentally, Venus rotates backward! Something must have hit it very hard; it was completely flipped over by the impact. — *Phil Plait*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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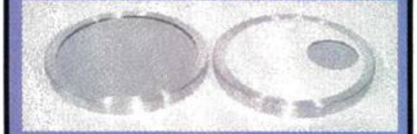

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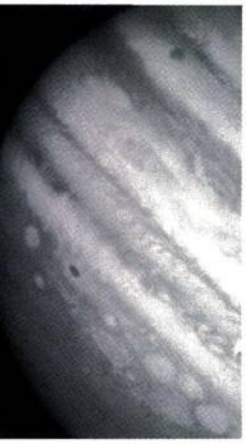

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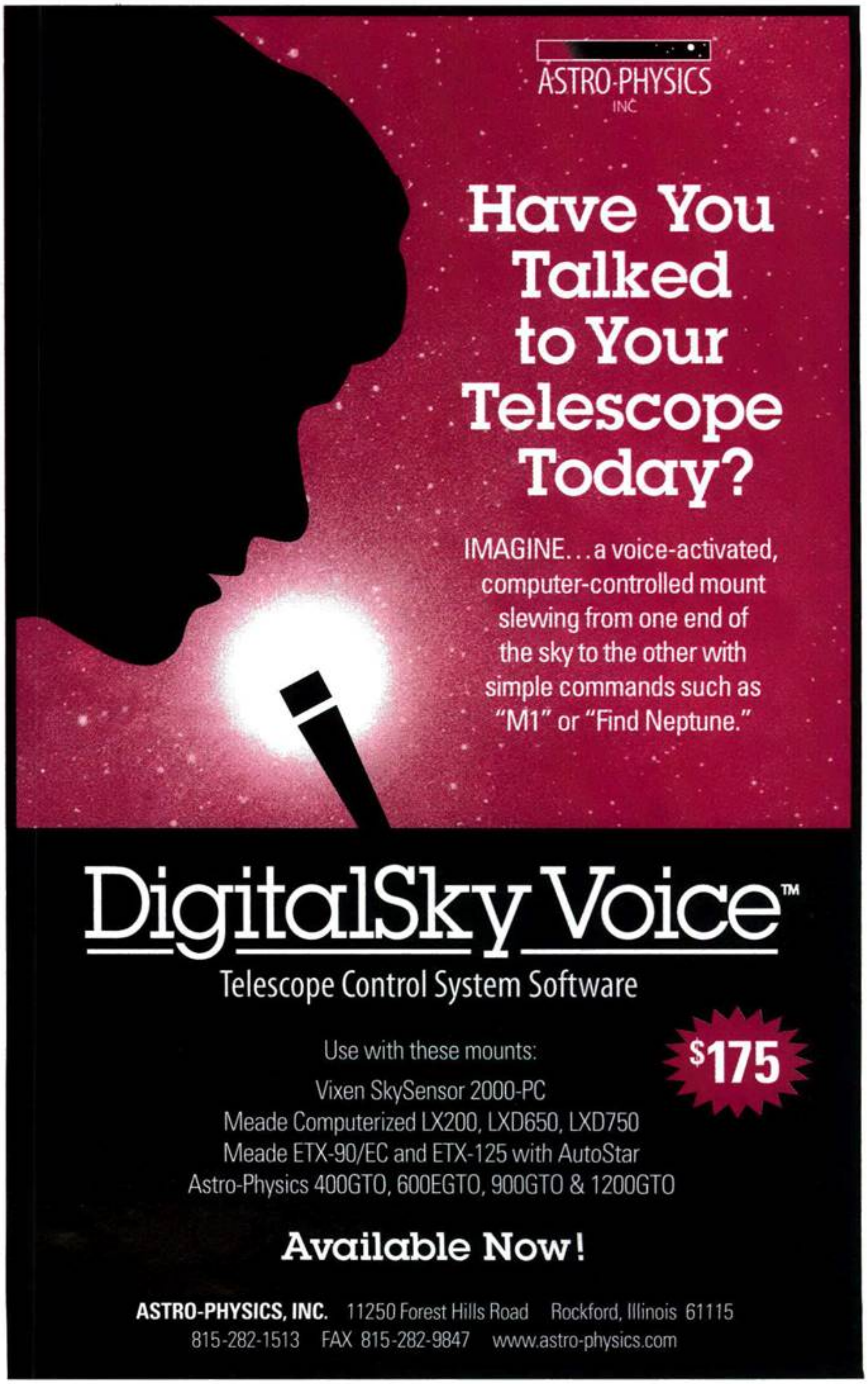

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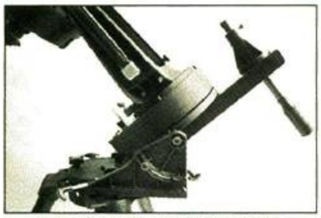
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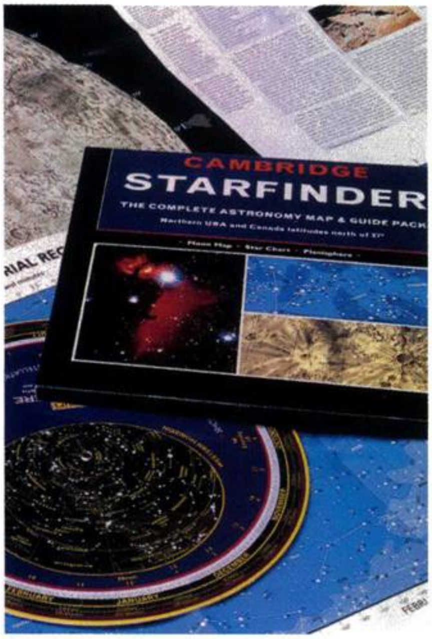
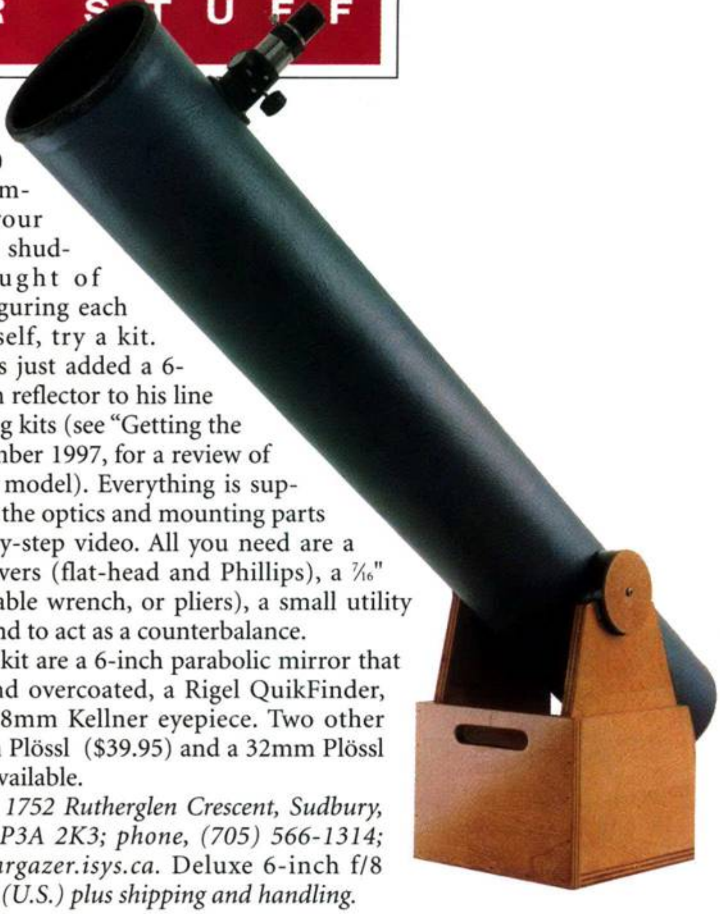


The second item is a moon map that depicts 500 craters on the moon's nearside. Landing sites, including those of the Apollo missions, are also marked.

Finally, the kit includes a planisphere for locating stars and constellations at any hour or date of the year. Observers in Canada and the U. S. located north of an arc through San Francisco, St. Louis, and Washington, D.C. will need the 42° version. Those in states south of this arc require the 32° version.

Cambridge University Press, Customer Service Department, 110 Midland Avenue, Port Chester, NY 10573; phone, (800) 872-7423; e-mail, orders@cup.org; website, http://www.cup.org. The Cambridge Starfinder: *$24.95 plus shipping and handling.*

Stargazer Steve Dob



▶ If you've contemplated building your own telescope but shudder at the thought of making and configuring each component yourself, try a kit. Stargazer Steve has just added a 6-inch f/8 Newtonian reflector to his line of telescope-making kits (see "Getting the Right Start," December 1997, for a review of the 4.25-inch f/10 model). Everything is supplied, including all the optics and mounting parts as well as a step-by-step video. All you need are a hammer, screwdrivers (flat-head and Phillips), a 7⁄16" wrench (or adjustable wrench, or pliers), a small utility knife, and some sand to act as a counterbalance.

Included in the kit are a 6-inch parabolic mirror that is hand figured and overcoated, a Rigel QuikFinder, and a 1.25-inch 18mm Kellner eyepiece. Two other eyepieces, a 7.5mm Plössl ($39.95) and a 32mm Plössl ($49.95), are also available.

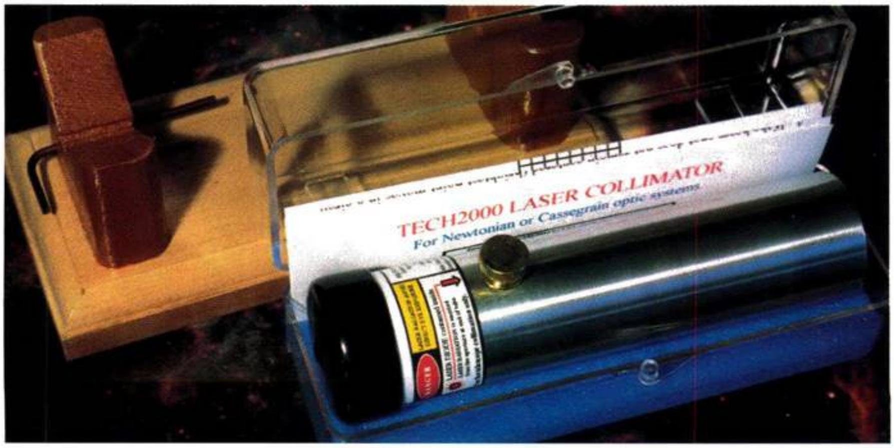
Stargazer Steve, 1752 Rutherglen Crescent, Sudbury, Ontario, Canada P3A 2K3; phone, (705) 566-1314; website, http://stargazer.isys.ca. Deluxe 6-inch f/8 Reflector Kit: *$379 (U.S.) plus shipping and handling.*

Laser Collimator

▶ How do you know your collimator is accurate? Does it allow calibration adjustments? Mirror alignment is critical to image quality for Newtonian reflectors and Schmidt-Cassegrain telescopes. The T2K Laser Collimator from TECH2000 includes a calibrating cradle and key so that accuracy can be verified. Users can even select the focal length of the instrument being tested.

The collimator uses a Class IIIa, low-power, 650nm-wavelength (red) laser that projects a beam visible even in daylight. The unit itself is machined from high-tempered aluminum with a long barrel, allowing targets to be seen easily even in deep focusers. The collimator fits 1.25-inch focusers, but a 2-inch adapter is available. It comes with batteries, the calibrating cradle and key, a clear showcase, and instructions.

TECH2000, 3349 Route 99 South, Monroeville, OH 44847; phone, (419) 465-2997; fax, (419) 465-2484; e-mail, tddi@accnorwalk.com; website, http://www.accnorwalk.com/~tddi/tech2000. T2K Laser Collimator: *$89 plus shipping and handling.*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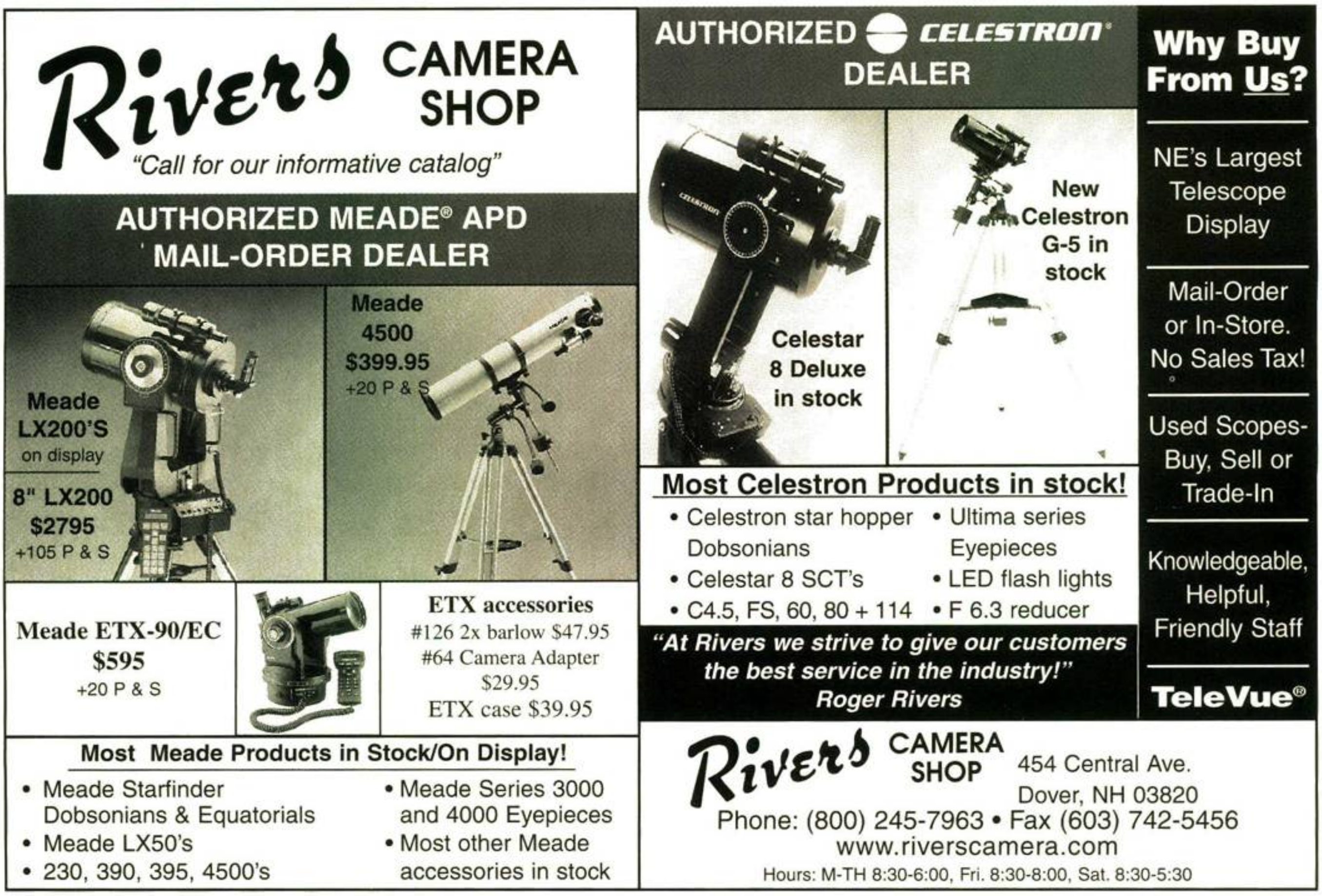

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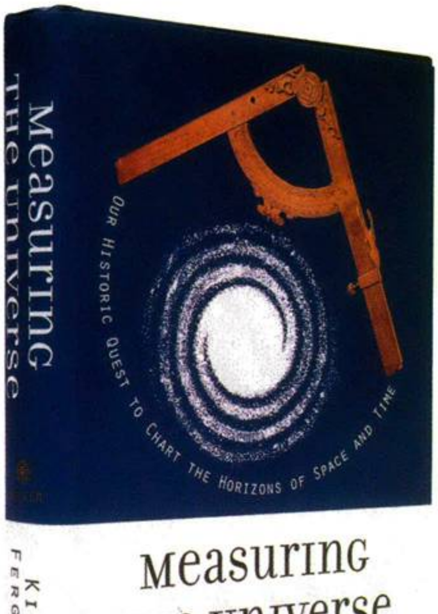
BOOKS

Measuring the Universe: Our Historic Quest to Chart the Horizons of Space and Time

Kitty Ferguson, 331 pages, Walker and Co., New York, 1999; ISBN 0-8027-1351-3; hardcover, $25.

▶ "This work is a chronicle of how men and women, over the course of two and a half millennia, have built a ladder of measurement from their doorsteps to the borders of the universe, and how the adventure has changed ideas about the shape and nature of the universe and our place in it." Thus science writer Kitty Ferguson, author of *Stephen Hawking: Quest for a Theory of Everything* and *Black Holes: Prisons of Light*, describes her engaging new book.

Ferguson takes readers on a journey through time and thought as humans learned to measure seemingly impossible expanses such as the diameter of Earth and the dimensions of the universe. Because of the impracticality of taking out a yardstick and counting off the inches and feet, people devised ingenious methods involving simple geometry in order to measure these seemingly immeasurable distances.

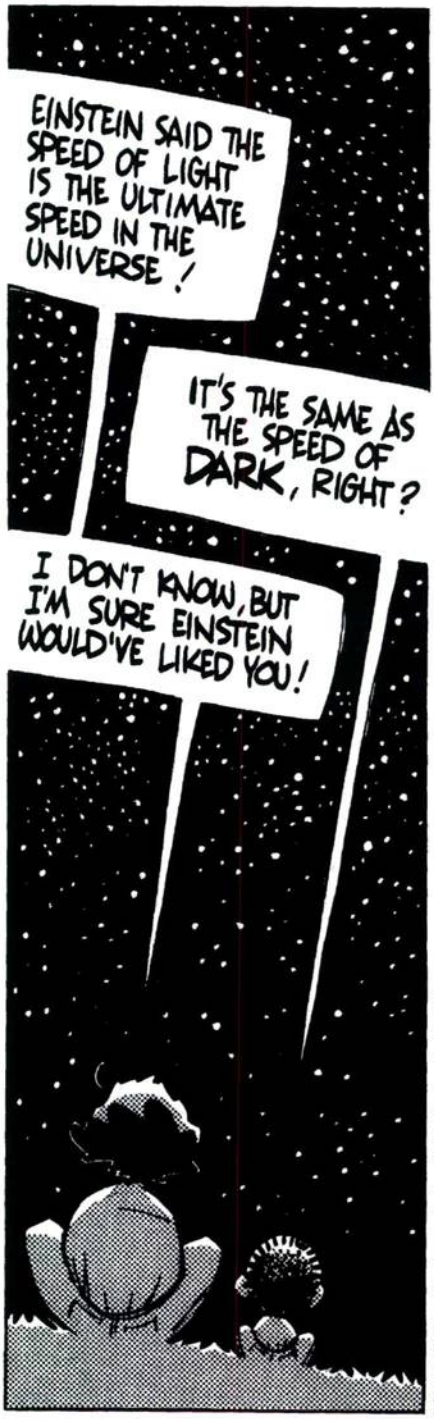


The first chapters are filled with accounts of the lives and accomplishments of the ancient luminaries: Eratosthenes, Aristarchus, Copernicus, Galileo, Cassini, and Newton, among others. Their discoveries are easy to grasp. From our perspective, the Earth-moon distance, a sun-centered solar system, and elliptical orbits are innately familiar. The lives of these pioneering thinkers and their simple but profound revelations make for easy reading.

For me, the most engrossing section of the book was Ferguson's account of Galileo's confrontation with the Catholic church. "The most outspoken and dogmatic reactions came not from churchmen but from conservative astronomers in the universities," she writes, "who continued to insist that the authority of Aristotle and Ptolemy must not be questioned." Church leaders had no desire to enter into the fray, but Galileo demanded they take a position, and, unfortunately for him, they sided against him.

In chapter 5, the narrative shifts gears as it moves to more recent times. Currently, many astronomers are working on a multitude of complex questions. As the cast of characters expands, so does the universe that is being measured. The tone becomes more scientific, as personalities are left by the wayside and talk of cosmic microwave background radiation, standard candles, and omega becomes the norm.

The math involved in the measurements is explained clearly and kept to a minimum, but sometimes too much so. In five pages, a step-by-step and painstakingly detailed instruction on how to measure parallax shift (a method used to find distances to nearby stars) stops just short of providing the equation. This prevents readers from plugging in their own numbers. It's like having an instruction booklet with the last page torn out. But it's a small flaw in an otherwise excellent book.


EINSTEIN SAID THE SPEED OF LIGHT IS THE ULTIMATE SPEED IN THE UNIVERSE!
IT'S THE SAME AS THE SPEED OF DARK, RIGHT?
I DON'T KNOW, BUT I'M SURE EINSTEIN WOULD'VE LIKED YOU!

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Measuring the Universe documents the history of humanity's inventiveness in discovering the distance scale of Earth and the cosmos. With more than 60 illustrations of the individuals and concepts that changed the way we view the universe, the book is sure to entertain and engage armchair astronomers. — *Kelly Whitt*

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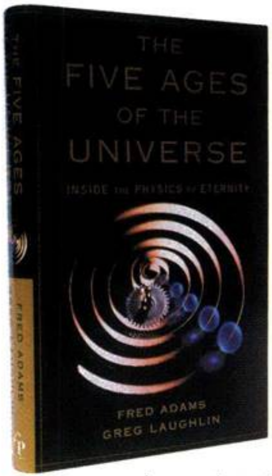
The Five Ages of the Universe: Inside the Physics of Eternity

Fred Adams and Greg Laughlin, 256 pages, Free Press, New York, 1999; ISBN 0-684-85422-8; hardcover, $25.

▶ If you want to see into the future, forget psychic hot lines. This new work by Fred Adams and Greg Laughlin takes you from the moment of creation to beyond what they call the one hundredth "cosmological decade" and the destruction of the universe as we know it.

With a basic understanding of physics and math, you can travel with Adams and Laughlin as they make their way through the physical history and future of the universe. The journey begins in the "Primordial Era," a time when only radiation exists. There are no stars or galaxies. The second age, our current star-rich "Stelliferous Era," is a time when stars actively form, live, and die. But that comes to an end in the "Degenerate Era," when all stars die and light is extinguished. The fourth period is a time when black holes dominate space the way galaxies do today. It is followed by "heat death" and the "Dark Era," a time when the universe becomes a thoroughly inactive place.



From its hot and explosive beginning, the book leaves a profound legacy of a universe in unfathomable darkness and a cold, limitless future.

PRODUCT INFO

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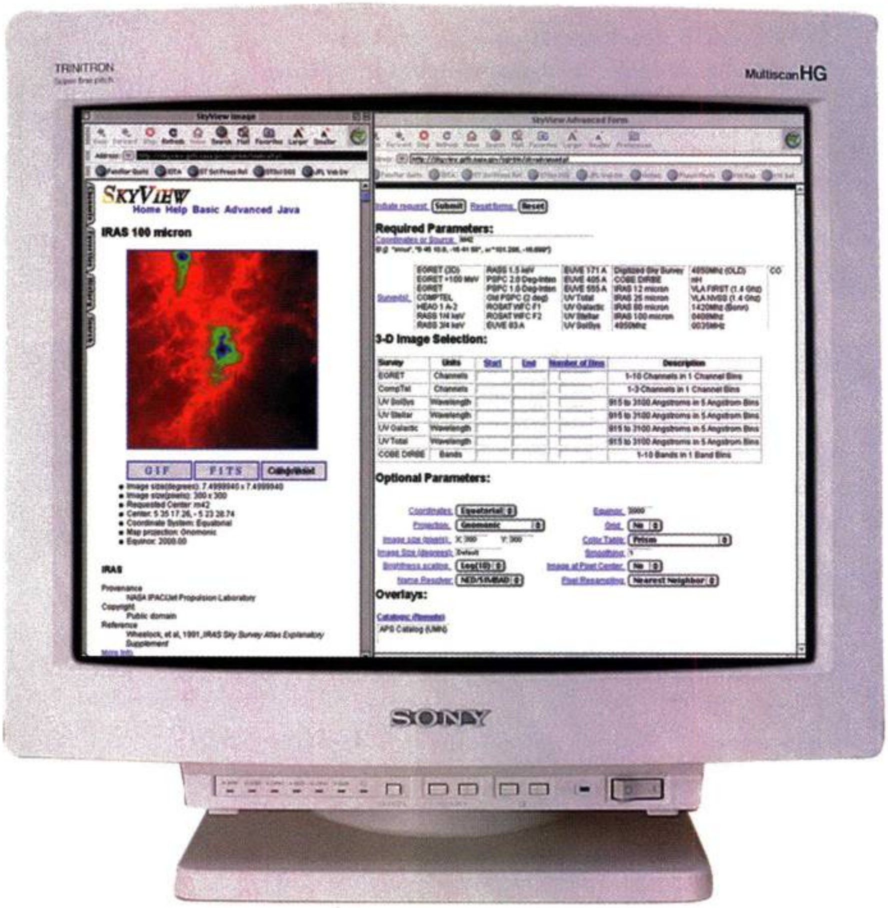

BYTES

View the Sky

▶ Want to see the Orion Nebula (M42) at infrared or ultraviolet wavelengths? *SkyView* (http://skyview.gsfc.nasa.gov) from NASA's Goddard Space Flight Center can help. This virtual observatory was developed for professional astronomers, but advanced and novice hobbyists will enjoy it as well. The program generates images of the sky at wavelengths from radio to gamma rays. Users tell *SkyView* the position, scale, and orientation desired, and the program yields an image made to order.

SkyView has two primary interfaces: a web interface and an interactive interface. The web interface uses HTML forms to format a request while the interactive interface uses a Java applet that works with your browser.

Within the web interface, there are three HTML forms. The first is for "non-astronomers" and is designed to allow quick access to *SkyView*. The primary option allows users to view selected objects in different wavelengths. It is ideal for the novice.

The "basic" interface offers a simple web-form query page that allows users to retrieve images from one or more surveys. Options for viewing specific coordinate systems, projections, equinoxes, brightness scales, and coordinate grids are also available.

The final web interface is for advanced users. Its more complex form permits detailed control of the image, as well as allowing the production of contours, a 3-color image, a 3-D image, and catalog overlays.

The interactive Java interface has all of the advanced functions (with the exception of 3-D and 3-color images), but also allows changes to color tables, overlays, image sizes, zoom levels, and other simple manipulations. The developers intend to enhance this version as the Java language matures.

X-Windows and Telnet interfaces are also available, but these are being phased out in favor of Java. ■

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For more information, contact Jackie Diehl, c/o the Space Center Education Department, Hwy. 2001, Alamogordo, NM 88349; (505) 437-2840; e-mail, jdiehl@zianet.com; website, http://www.zianet.com/aacwp/wssp.html.

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SEPTEMBER 3
Stargazer — Kids' Night

▶ Summit House Restaurant, The Big Mountain, Whitefish, Montana. Contact Syd Ryerson, The Big Mountain Ski and Summer Resort, P.O. Box 1400, Whitefish, MT 59937; (406) 862-2900; website, http://www.bigmtn.com.

SEPTEMBER 8–12
Alberta Star Party

▶ Eccles Ranch Observatory, near Caroline, Alberta, Canada. Contact Rick and Carol Weis, 4612 17th Ave. N.W., Calgary, Alberta T3B 0P3; (403) 286-4347; website, http://www.syz.com/rasc/asp.htm.

SEPTEMBER 9–12
Oregon Star Party

▶ Indian Spring Trail, Ochoco National Forest, Oregon. Contact the Oregon Star Party, 16016 S.E. Division, Suite 307, Portland, OR 97236; Chuck and Judy Dethloff, (503) 357-6163.

SEPTEMBER 10
Wyoming Star Summit

▶ Lincoln Monument Rest Area, east of Laramie, Wyoming. Contact Scott Mecca, (307) 635-1511; e-mail, scmecca@wyoming.com.

SEPTEMBER 10–11
Abegweit Autumnal Astronomical Adventure

▶ Bayview, Prince County, Prince Edward Island, Canada. Contact Bill Thurlow, 1 Carol Avenue, Summerside, Prince Edward Island C1N 2K5; e-mail, wthurlow@auracom.com.

SEPTEMBER 10–11
Craters of the Moon Fall Star Party

▶ Craters of the Moon National Monument, between Arco and Carey, Idaho. Contact Jay Sneddon, (208) 736-2447; website, http://members.tripod.com/mvas/craters.html.

SEPTEMBER 10–11
Nightfall

▶ Palm Canyon Resort, Borrego Springs, California. Contact Nightfall, c/o Fox & Stephens, CPAs, 8300 Utica Avenue, Suite 105, Rancho Cucamonga, CA 91730; (909) 948-2205; website, http://www.rtmc-inc.org/nightfall.html.

SEPTEMBER 10–11
Northern Arizona Star Party

▶ Paulden, Arizona. Hosted by the Prescott Astronomy Club. Contact Gary Frey, P.O. Box 1114, Mayer, AZ 86333; (520) 632-7355; website, http://www.pacnet.org.

SEPTEMBER 10–12
Black Forest Star Party

▶ Cherry Springs State Park, north central Pennsylvania. Contact Central Pennsylvania Observers, P.O. Box 947, State College, PA 16801; website, http://www.starparty.homepad.com.

SEPTEMBER 10–12
Blackwater Falls Astronomy Weekend

▶ Blackwater Falls State Park, Davis, West Virginia. Contact Ron Cockeram, 5216 Bailey Road, Cross Lanes, WV 25313; (304) 776-5017; website, http://www.earth1.net/kvas/.

SEPTEMBER 10–12
Connecticut Star Party

▶ Colebrook, Connecticut. Contact

Bob Carruthers, 37 Saw Mill Drive, Wallingford, CT 06492; or Linda Marks, e-mail, sunandmoon@freewwweb.com.

SEPTEMBER 10–12
No Frills Star Party

▶ Tuckahoe State Park, Queen Anne, Maryland. Call Lyle Jones at (302) 736-9842; website, http://www.delmarvastargazers.org/.

SEPTEMBER 11
Blue Ridge Parkway Regional Stargaze

▶ Julian Price Park, Blue Ridge Parkway, North Carolina. For more information, send a SASE to Greg Kirby, 5026 Poplar View Lane, Granite Falls, NC 28630; (828) 396-7657.

SEPTEMBER 11
Free Public Star Party

▶ Ralph A. Worley Observatory, south of Shreveport, Louisiana. Contact Cran Lucas, (318) 797-1524; website, http://www.lsus.edu/nonprofit/sbas/.

SEPTEMBER 12
Island Lake Star Party

▶ Spring Mill Pond Picnic Area, Island Lake State Recreation Area, near Brighton, Michigan. Contact the Ford Amateur Astronomy Club, P.O. Box 7527, Dearborn, MI 48121-7527; (313) 390-5456; website, http://kode.net/~dougbock/faac/.

SEPTEMBER 17–19
Astrofest

▶ Camp Shaw-Waw-Nas-See, near Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact Astrofest, P.O. Box 596, Tinley Park, IL 60477-0596; voicemail, (773) 725-5618; website, http://www.chicagoastro.org.

SEPTEMBER 18
Hurricane Ridge Star Party

▶ Olympic National Park, Port Angeles, Washington. Coordinated by the Port Angeles High School Astronomy Club. Contact John Gallagher at (360) 452-0260; e-mail, jgalla@pasd.wednet.edu.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com. Look for additional events at http://www.astronomy.com.

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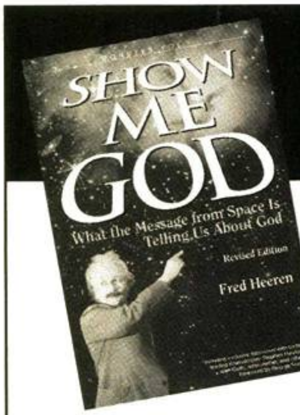

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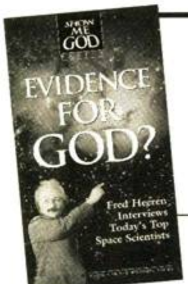

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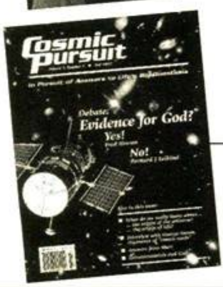

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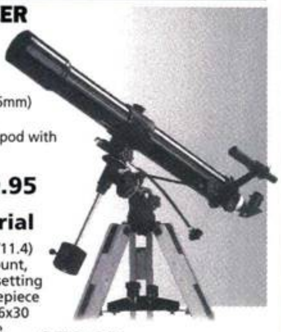

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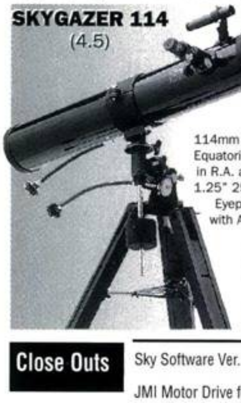

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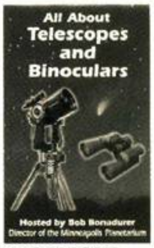
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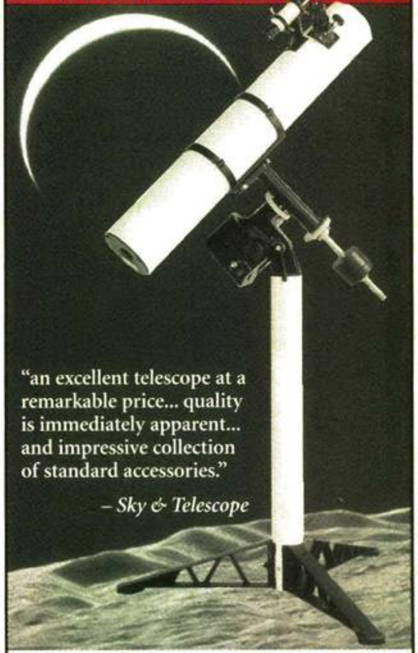

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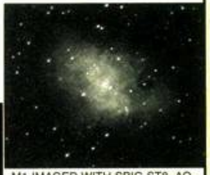

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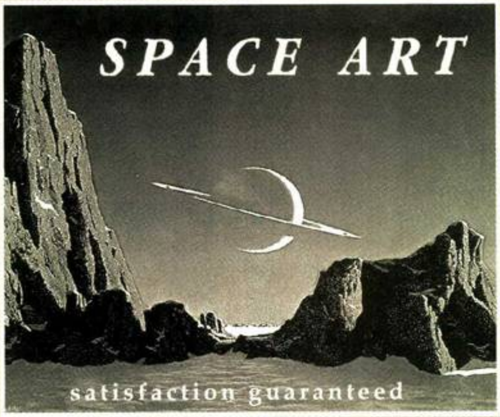

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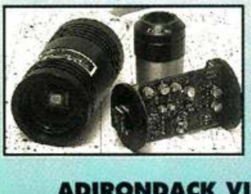

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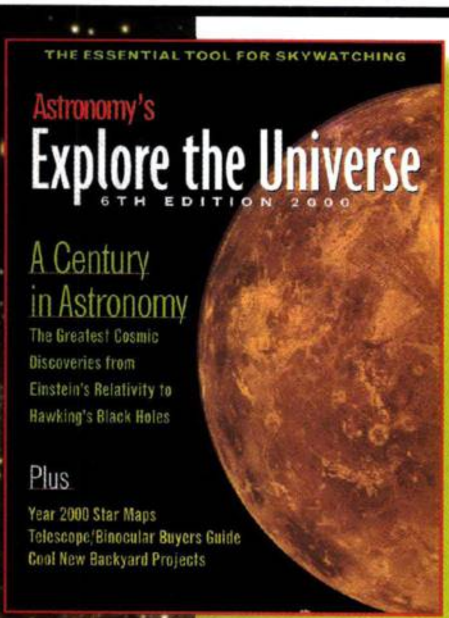
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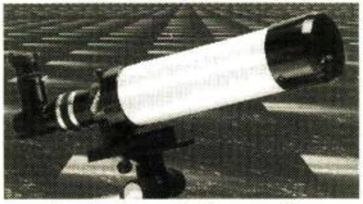

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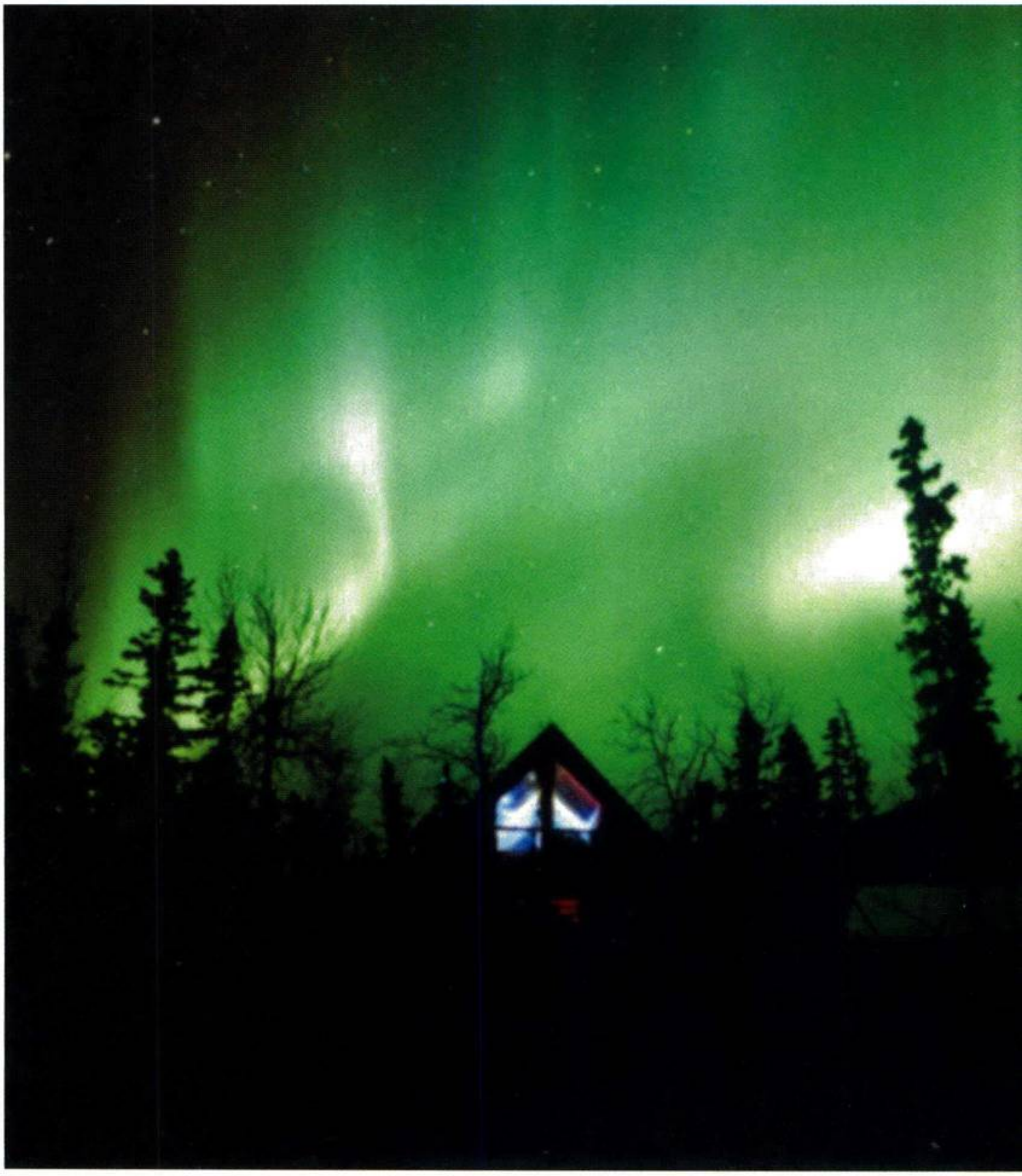
"That's Scorpius"

▶It all started at a high school graduation party in June 1963. As my date and I stumbled down the steps into a strangely quiet, summer-dark backyard, I heard a young male voice. "That's Scorpius," it said. "The bright star at its center is Antares, one of the brightest stars in the sky. Look straight up from Antares," the voice continued. "See the stars that look like an *H*? That's the constellation Hercules. And next to him is Lyra, with the super-bright star Vega, the beacon of the summer sky."

I'd had my share of crushes, but for the first time ever I fell for a nameless, faceless voice. Later, when the backyard lights came on, I saw the voice attached to a gawky, dark-haired boy. I told him how much I enjoyed his sky tour. Dennis and I soon spent many evenings skygazing. That winter we observed until neither of us could feel our hands or feet. It took us an hour to thaw. It took longer than that to convince my mother that I was, in fact, stargazing until 4 A.M.

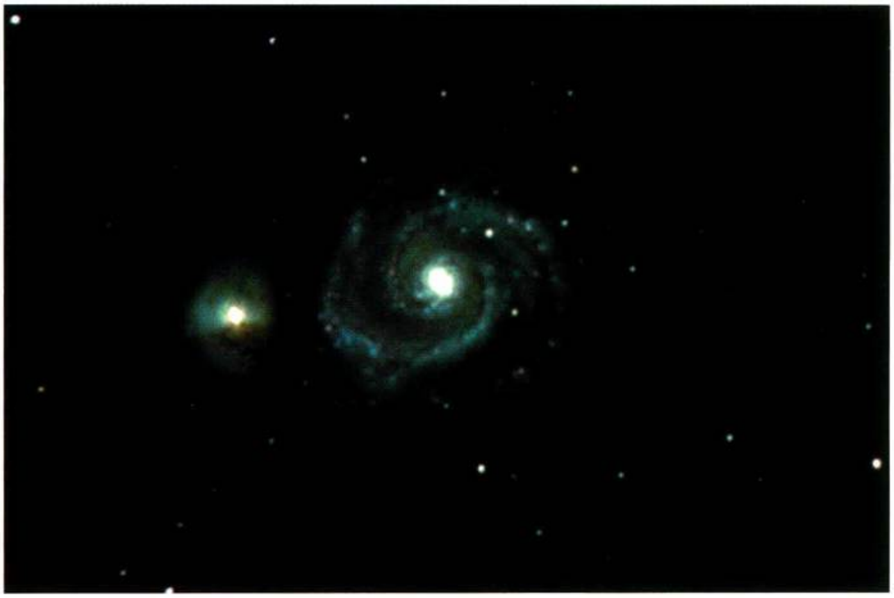
Dennis and I eventually married and had three children. When the kids were young we would drive our blue station wagon to a rented house in the Gogebic mountains, in the Upper Peninsula of Michigan. We'd bundle our offspring into bed early so we could wake them at 2 A.M. We'd then stuff them into their

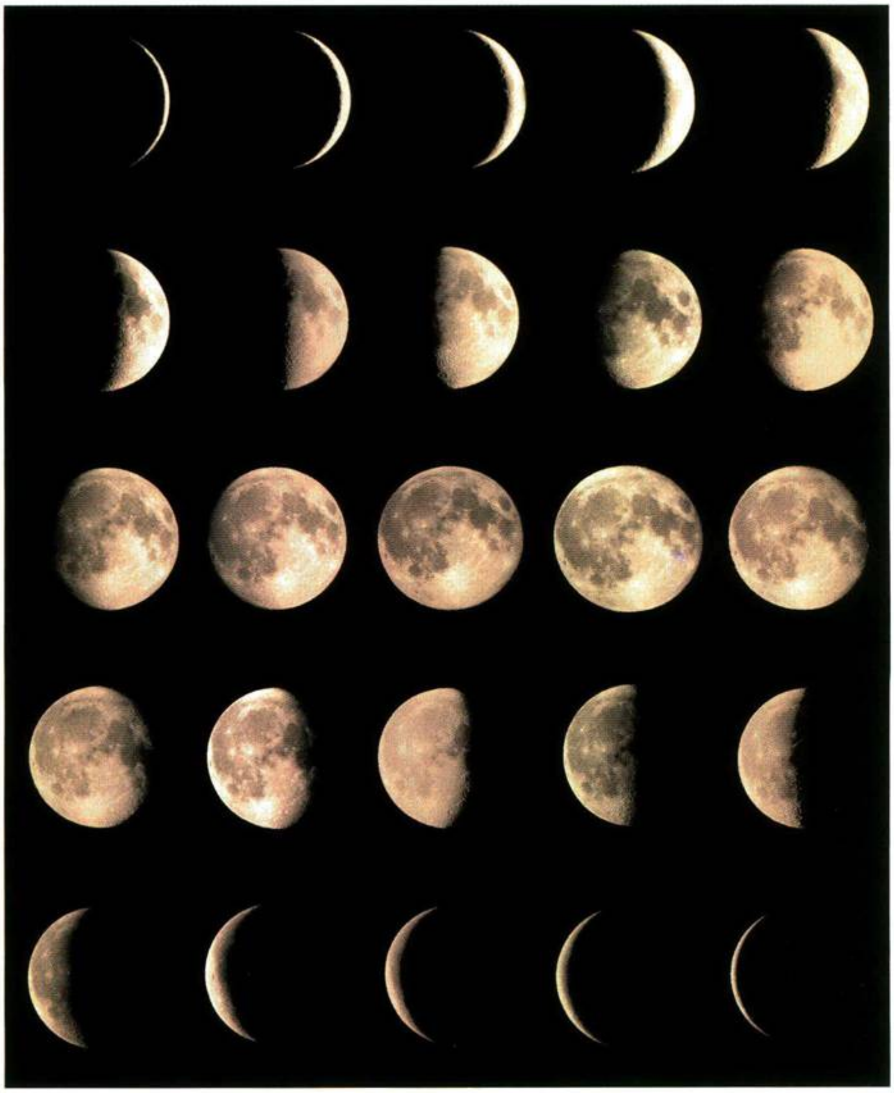


Surging Northern Lights

JIM EGGER

(28mm lens at f/2.8, 400 PPF Kodak film, 1-minute exposure taken March 7, 1998)





Magnificent M51

JIM EGGER

(26-inch f/5.4 reflector, 400 PPF Kodak film, 30-minute exposure)

A Lunar Month

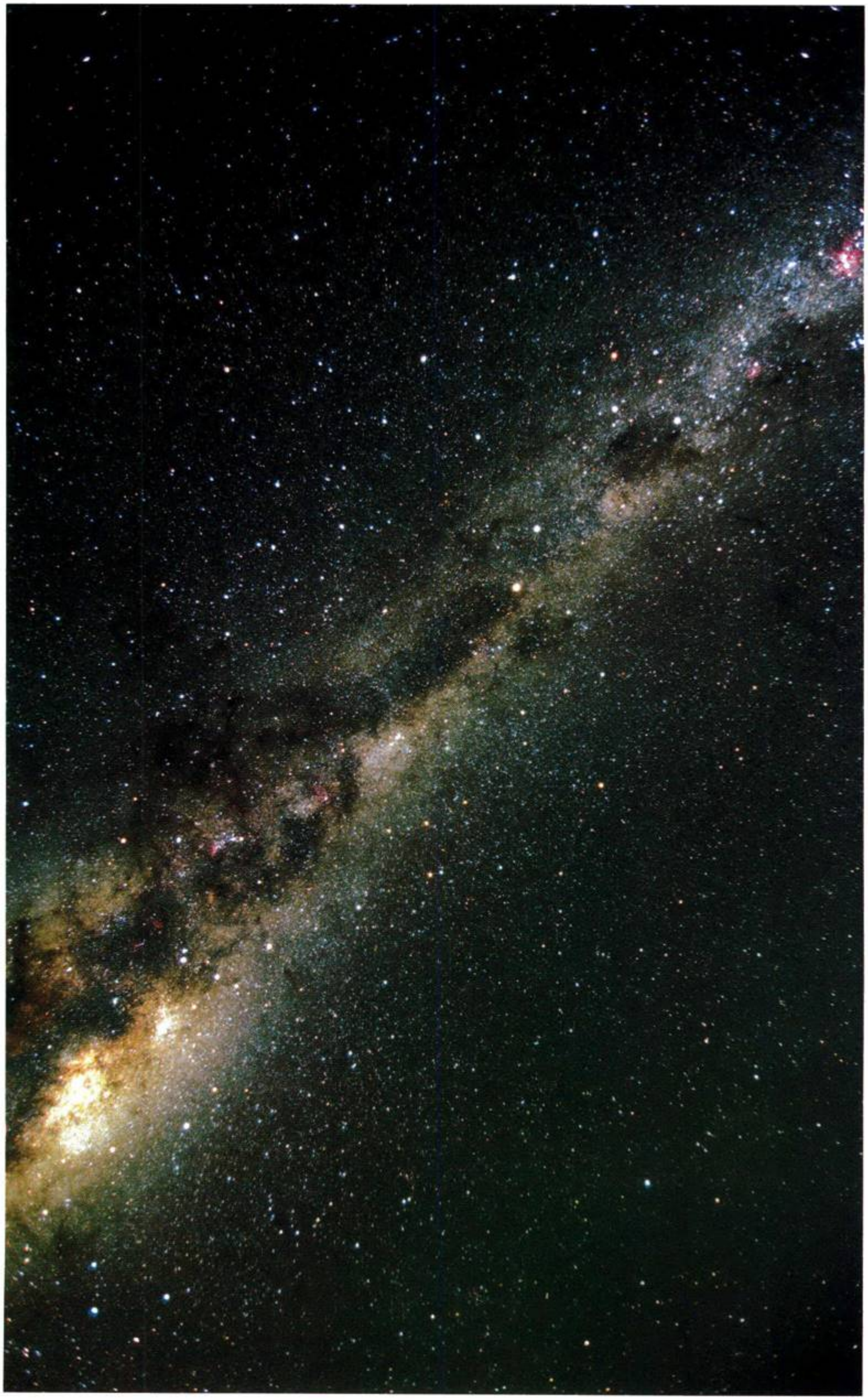
JOHN BUCCE

(8-inch f/10 SCT, Kodak 400 film, $\frac{1}{250}$ to $\frac{1}{60}$-second exposures taken over 11 months) snowsuits (it gets cold in Upper Michigan in August), drive up gravel roads to the top of a nearby hill, flip down the "tail" of the wagon, and cuddle up to watch the Perseid meteor shower. Once again, I'd listen to that lovely voice guiding a half-asleep audience across the summer skies, interrupted regularly by an excited "I saw one. It was over there!" Later, as the dawn began to break, we'd return to the house and look for the Seven Sisters, first with the naked eye, then through the telescope.

Years passed, and in 1995, our family once again traveled to Michigan for vacation. On August 12 or 13, after it got really dark, we bundled up and grabbed pillows and blankets before jockeying for position on the porch. We were barely settled before we realized that the previously clear skies were hazy. Then it hit us. Waves of light were emanating from the northern horizon. As we lay there, they began to turn colors: light blue, then green, then peach. They first pulsed slowly near the horizon, then surged across our entire field of view. We forgot the Perseids and watched the most spectacular sky show we'd ever seen.

It is always fun to watch Dennis guide someone through the night sky for the first time. Their reactions remind me of that graduation night over 35 years ago when I, for the first time, heard his voice say, "That's Scorpius."

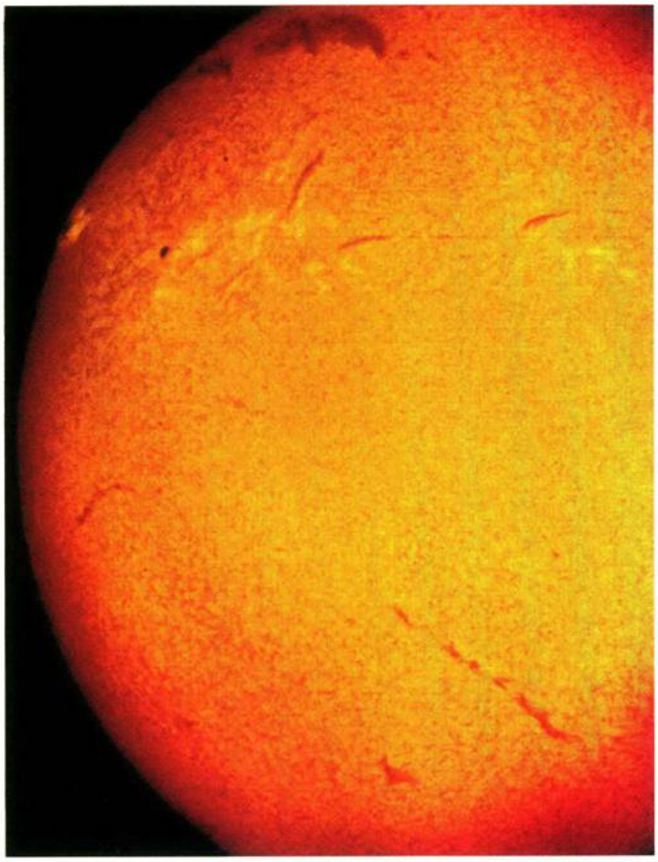
Judith Fradin lives in Evanston, Illinois, and is a children's book author and 23-year veteran teacher. She and Dennis have been married for 33 years.



The Southern Milky Way

MARK SCHROEDER

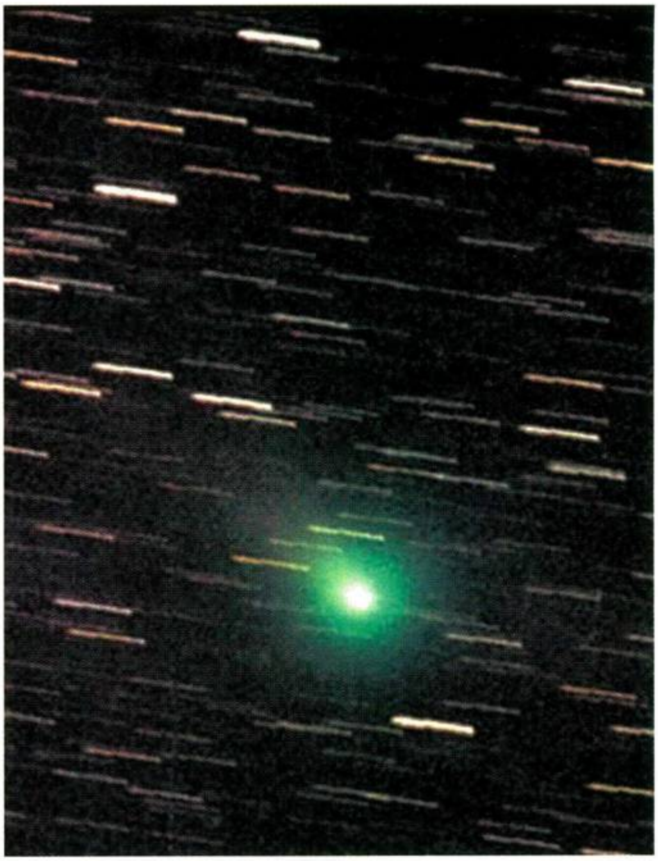
(17mm lens at f/2.8, Fuji 400 film, 20-minute exposure)



Scarred Sun

JEFFREY PETTITT

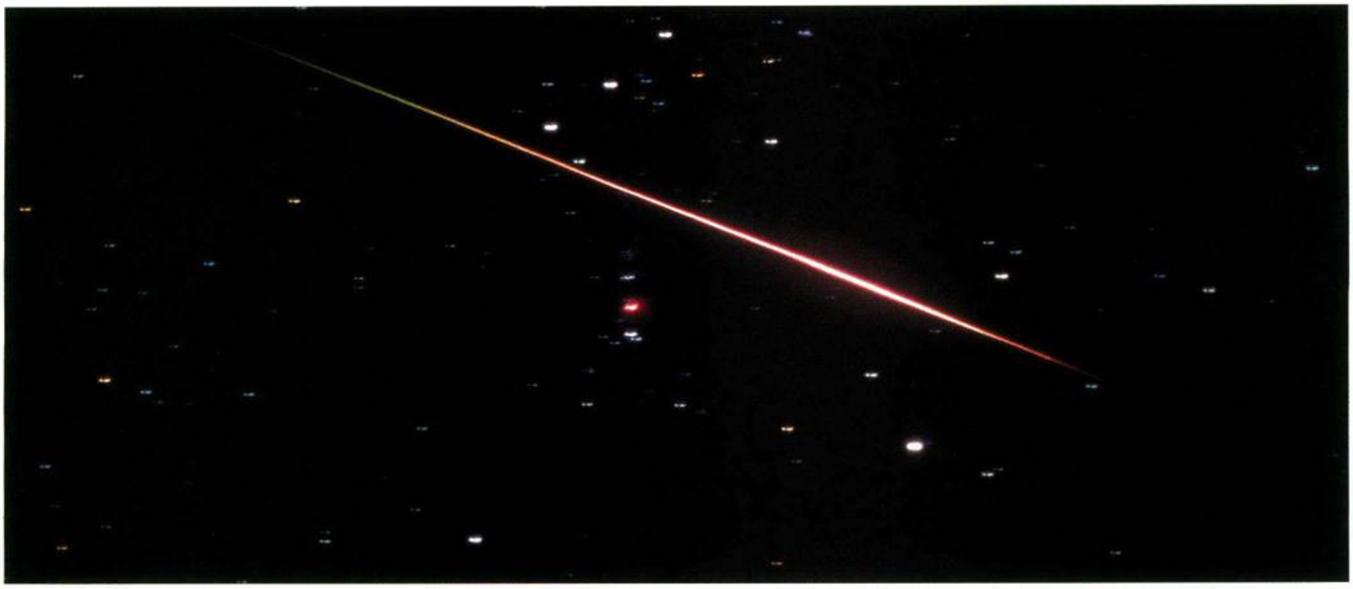
(10-inch f/12 refractor, Kodak Tech Pan 2415 film, Daystar Hα filter, 1/500-second exposure taken May 8, 1999)



Comet Lee

GERALD RHEMANN AND FRANZ KERSCHE

(6-inch f/8.3 refractor, Kodak Pro Gold 400, 120 format film, composite of 30-minute and 20-minute exposures taken May 18, 1999)

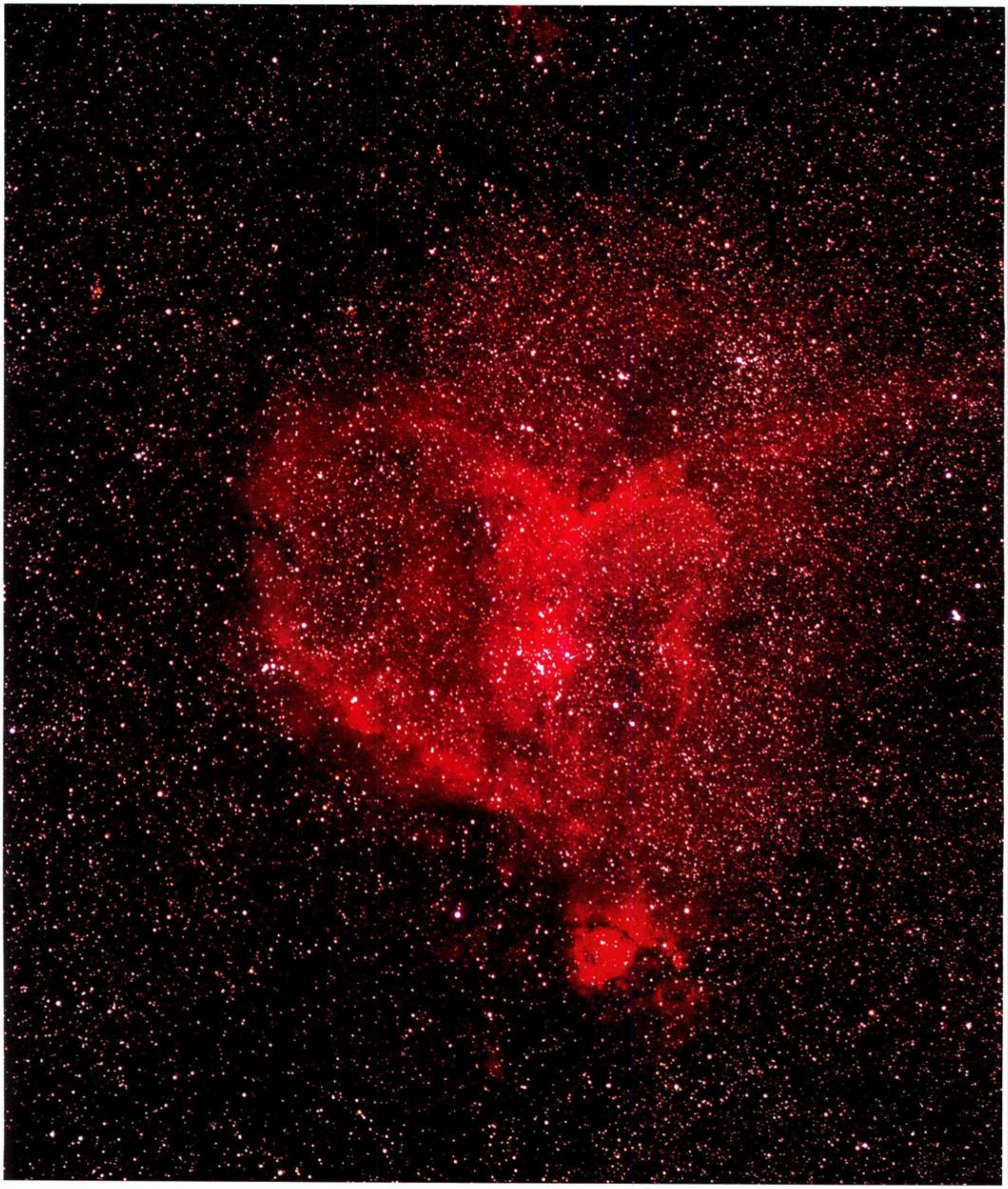


Leonid Meteor Pierces Orion

TERRY ATWOOD

(50mm lens at f/2.8, Kodak E200 slide film, 1-minute exposure taken November 17, 1998)

This month's best astrophoto



The Heart Nebula (IC 1805)

STEVE MANDEL

(5-inch f/6 refractor, Kodak Pro 400, 120 format film, composite of two 1-hour exposures)
This cluster and its heart-shaped nebulosity reside in Cassiopeia.

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See Page 115 for a Listing of Tele Vue Dealers

The Andromeda Galaxy (M31). A composite of 45-minute and 90-minute exposures by Jason Ware with the Meade Model 152ED 6" Apochromatic Refractor on hypered Fuji HG400 film. The two exposures were digitally scanned, stacked, and processed to form the final image shown here.

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